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Summary Report,
Risk Assessment Modeling Workshop

14-15 May 1998, New Orleans, Louisiana

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Final report

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Preface

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1 Introduction

Background

The Fate & Effects Advisory Committee (FEAC) identified the need for the development of models capable of providing information relating to the fate and effects of Military Relevant Compounds (MRCs) on both ecological and human resources. Stated was the requirement for better modeling capabilities of contaminant concentration over time for risk assessment. In an effort to address the requirement, a work unit was initiated for the development of an Army Risk Assessment Modeling System (ARAMS). This system will incorporate other research efforts conducted in the Fate & Effects research program and will enable thorough evaluation of ecological and human risk assessments.

The ARAMS will be developed for the purpose of conducting ecological and human risk assessments. Development of this system will incorporate current state-of-the-art modeling technologies and will further utilize concurrent research efforts in the Fate and Effects Research Program. The ARAMS is a tool to characterize, integrate, and estimate ecological risk. The system will provide several tiers of complexity such that screening level and complex models issues can be addressed. The system will include: (a) screening level assessments based on simple exposure-response relationships and limited spatial and temporal scales, (b) an expanded assessment capability based on linkage of more rigorous exposure and ecological assessment techniques and (c) linkage of ecological risk, comprehensive exposure models, and integrated temporal-spatial exposure,...i.e., probabilistic estimate of exposure for individuals/population in time and space.

Objective

The objective of this workshop was to ascertain the current state-of-the-art in risk assessment modeling and to facilitate discussion of the components required for an ARAMS.

Presentations

The presentation topics at the workshop were selected to provide a foundation for the discussion of the development of ARAMS. Each topic was considered to be a potential building block for the conceptualization of the system. The topics presented were: Ecological Risk Assessment Concepts; A WEB-Based Approach for Developing Risk Assessment Modeling System; The Groundwater Modeling System; The Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES); Dredged Material Modeling—Risk-Based Concepts, Bioaccumulation Modeling Concepts, and Principles/Contemporary Issues; Ecosystem Models for Ecological Risk Analysis: Single Species to Communities; You Don't Need to Know a Lot of Ecology to Make a Comprehensive Ecological Risk Assessment; Risk Analysis of Potentially Contaminated Sites Using the U.S. Environmental Protection Agency (EPA) MMSOILS Multimedia Model; Metapopulation Models and Ecological Risk Analysis: A Habitat-Based Approach to Biodiversity; Ecological Risk in an Integrated Intermedia System, and Exposure Assessment - Trophic Transfer to Birds. A brief description of the topics presented at the workshop follow. Appendix A presents the "Conference Agenda and List of Participants." Copies of the actual presentation documents from each speaker at the workshop are shown in Appendixes B through K with the exception of "A WEB-Based Approach for Developing Risk Assessment Modeling System" and "The Groundwater Modeling System." Hard copy versions of these two presentations were not available.

Ecological risk assessment concepts

Ecological risk assessment modeling may be broken down into four areas of interest: (1) problem formulation, (2) exposure assessment, (3) effects assessment, and (4) risk characterization. The Department of Defense (DoD) has historically emphasized human health protection, but ecological concerns are becoming more prominent.

An ecological risk assessment survey of 190 Army facilities indicated that more than 50 percent were/anticipated conducting ecological risk assessments. DoD risk assessment needs include (a) modeling/software tools for risk characterization, (b) modeling/software tools for projecting effects beyond individual organisms, (c) modeling/software tools for incorporating spatial and temporal issues when assessing risk, and (d) modeling/software tools for quantifying uncertainties.

WEB-based approach for developing risk assessment modeling system

A web-based approach was presented to demonstrate the utility of updating and maintaining databases via the Internet. The newly developed Land

Management System (LMS) was given as an example. This system contains components of the Watershed Modeling System (WMS), and a demonstration of was presented showing how the CASC2D hydrologic model within the WMS could be initialized and run across the Internet. The United States Geological Survey's (USGS) topographical databases were accessed and dowloaded incorporating the WEB-based approach. This downloaded information could then be used to setup the grid structure for the CASC2D model. A previously developed CASC2D model application was then run (in an effort to save time) from a remote access site to display the features of incorporating offsite computing resources for conducting modeling runs or scenarios.

Groundwater modeling system

The Groundwater Modeling System (GMS) was developed by the DoD in partnership with the Department of Energy, the U.S. Environmental Protection Agency, Cray Research, and 20 academic partners. The GMS provides an integrated and comprehensive computational environment for simulating subsurface flow, contaminant fate/transport, and the effectiveness of remediation design alternatives.

GMS integrates and simplifies the process of groundwater flow and transport modeling by bringing together all of the tools needed to complete a successful study including both pre- and postprocessing tools. GMS provides a comprehensive graphical environment for numerical modeling, tools for characterization, model conceptualization, mesh and grid generation, geostatistics, and sophisticated tools for graphical visualization. The system is also currently available for both PC- and UNIX-based operating systems. Several types of models are supported by GMS. The current version of GMS provides a complete interface for the codes FEMWATER/LEWASTE, MODFLOW, MODPATH, MT3D, RT3D, and SEEP2D . Anticipated model additions in the future include UTCHEM, NUFT3D, ParFlow, and ADH.

The framework for risk analysis in multimedia environmental systems (FRAMES)

FRAMES is a software platform that allows models, developed by different people, to link and communicate with each other, while maintaining the legacy of the original models. FRAMES provides several functions: (a) it allows users to implement preferred models, (b) it allows users to link preferred models to and communicate with other models, (c) it allows for a standard, base set of models (regulatory review), (d) it maintains the legacy of models, (e) it provides a "plug-and-play" environment, and (f) it helps the user with the conceptual site model. The traditional multimedia modeling approach involves thinking in the abstract with complex flow charts for inputs, transport pathways, exposure routes and outputs, but FRAMES offers a nontraditional approach which offers the multimedia modeler the capability to conceptually build the system to be modeled through a graphical user interface (GUI) and drag and drop modules.

The modules communicate to other modules through the use of data processors and a data standard specification which is built into the FRAMES user interface.

Dredged material modeling—Risk-based concepts

Technical evaluation of the environmental acceptability of dredged material disposal is an effects-based process compatible with risk assessment. Computer programs and databases have been developed to aid in the evaluation and include the Automated Dredging and Disposal Alternatives Modeling System (ADDAMS) and the Environmental Effects Determination Database (E2D2). ADDAMS) is a PC-based system for DOS and Windows 95. It is a collection of 16 modules which are simple, nonintegrated, computerized tools and models for dredged material management and environmental effects evaluation. The modules in ADDAMS are predominantly stand-alone screening-level models linked under a common shell or menu. E2D2 is a web-based database of literature on environmental effects of contaminant residue in tissue of aquatic organisms. It provides for the interpretation of bioaccumulation data to determine environmental significance in absence of criteria.

Bioaccumulation modeling concepts and principles/contemporary issues

The allowable dose for any animal anywhere in an aquatic system is the intake from water ingested plus the intake from food/prey ingestion. We can define the bioconcentration factor (BCF) as the ratio of chemical contaminant in food-to-water concentration for exposure to water only. The major advantages of this are (a) that the BCF is easily determined in the laboratory under controlled conditions with "standard" (small) fish and (b) it is not dependent on site characteristics. This method allows for a neat and clean, site-independent national water quality criterion (WQC). If a WQC is used that is based on a bioaccumulation factor (BAF) which is dependent on the food web, a not-so-neat-and-clean method results. This method is site dependent and makes a national WQC possible only for a generic food web.

How do you determine the allowable waste load allocation of chemicals that may bioaccumulate? The proposed approach is to regulate on allowable tissue concentration at assigned frequency of exceedance percentile and to determine the allowable frequency distribution of chemical input load.

Ecosystem models for ecological risk analysis: Single species to communities

To justify regulatory and mitigation decisions, toxicologists are often asked the "so what?" questions that demand predictions about the population or even ecosystem response to contamination. Ecotoxicology is microcomputer software specifically created to help toxicologists answer such questions by extrapolating

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effects on organisms observed in bioassays to their eventual population-level consequences. It provides a software shell from which users can construct their own models for projecting toxicity effects through the complex filters of demography, density dependence, and ecological interactions in food chains. It allows various standard choices about low-dose response models, which vital parameters are affected by the toxicant, the magnitudes and variabilities of these impacts, and species-specific life history descriptions. During the calculations, the software distinguishes between measurement error and stochastic variability. It forecasts the expected risks of population declines resulting from toxicity of the contaminant and provides estimates of the reliability of these expectations in the face of empirical uncertainty. This risk-analytic endpoint is a natural summary that integrates disparate impacts on biological functions over many organizational levels.

You don't need to know a lot of ecology to make a comprehensive ecological risk assessment

There are five problems which lead to lack of trust in the risk analysis: (1) tool for obstructionists, (2) help for the other side, (3) need for too much data, (4) too expensive (requires consultants), and (5) too complicated. A good uncertainty analysis can alleviate the last three problems, and even though uncertainty is often large, it may still permit clear decisions.

There are three major problems with risk analysis: (1) correlation and dependency are ignored, (2) input distributions are unknown, and (3) mathematical structure is questionable.

Correlations and dependencies in uncertainty analysis are typically based on one of the following independence assumptions: dispersive Monte Carlo sampling, or dependency bounds analysis. Dispersive Monte Carlo sampling assumes extreme correlations so the result is as broad as possible. It is also computationally cheaper than ordinary Monte Carlo methods.

The default distributions for unknown input distributions are typically maximum entropy or probability bounds (P-bounds). Maximum entropy generalizes Laplace's Principle of Insufficient Reason and yields a distribution with minimum bias and maximum uncertainty under the constraints. Probability bounds (min, max, mean, median, shape, etc.) and P-bound arithmetic are quicker than Monte Carlo and are guaranteed to bound answer and provide the optimal solutions in most cases.

A questionable mathematical structure can be made more sound by incorporating a comprehensive battery of checks and incorporating model uncertainty into the analysis. The battery checks should provide general checks (e.g., dimensional and unit concordance) and checks against domain knowledge (e.g., population size nonnegative). The advantages of P-bounds as the uncertainty tool are: (a) much faster than second-order Monte Carlo, (b) easy (graphical) parameterization, (c) handles uncertainty about parameter values,

distribution shapes, dependence and correlation among variables, even the form of the model itself, and (d) faithful to most frequent interpretation.

Risk analysis of potentially contaminated sites using EPA's MMSOILS multimedia model

The purpose of this presentation is to provide an introduction to the MMSOILS model, its uses and limitations, and to demonstrate how MMSOILS was used in one EPA program, Hazardous Waste Identification Rule (HWIR), to provide an initial assessment of many sites. Some selected features of MMSOILS multimedia model are

a. Contaminant transformation and fate processes

b. Intermedia contaminant fluxes

c. Exposure pathways

d. Human health risk measures

e. Media-specific transport.

The purpose of EPA's HWIR is to evaluate if certain low-risk wastes can be disposed of as nonhazardous. The EPA "Exit" Rule is the question : at what concentrations can specific chemicals "exit" hazardous waste disposal requirements and be protective of human health and environment? The scope of HWIR is nationwide and is specific to chemicals and waste management unit (WMU) types. HWIR specifies approximately 400 chemicals and WMU types of landfill, impoundments, and waste piles. EPA's approach to implementing HWIR is through a multimedia/multipathway, risk-based(human health and ecological), and site-based (create plausible sites and assume each chemical could be disposed at each site) methodology.

Factors that influence computational effort to implement HWIR are: (a) there can be hundreds of sites, (b) five to six source types, (c) 400 plus chemicals, (d) the range of source concentrations, and (e) Monte Carlo loops. The computational burden on a computer processing unit (CPU) to implement a modeling scenario can easily approach centuries when Monte Carlo uncertainty is used. Means to reduce computational burdens, such as making use of linearity, grouping of chemicals, risky versus nonrisky sites, and minimizing the number of random variables are required.

Metapopulation models and ecological risk analysis: A habitat-based approach to biodiversity

Metapopulation dynamics are important in ecological risk analysis, and modelers ignore spatial structure at their own risk. Spatially explicit

metapopulation models provide practical compromise between complexity and applicability. Future directions for ecological risk analysis modeling will be to incorporate habitat relationships, involve multispecies approaches, and allow metapopulations in trophic chains. Metapopulation models are important because they allow assessment of impacts, evaluate management options at the metapopulation level, and also allow complicated population dynamics to be simulated.

Factors that affect population dynamics are:

a. Demography: survival, fecundity, and growth.

b. Age or stage of structure.

c. Density dependence.

d. Environmental fluctuations, catastrophes.

e. Demographic stochasticity.

Factors that affect metapopulation dynamics include all of the ones for population dynamics, but additionally include:

a. Number of populations.

b. Geographic configuration.

c. Spatial correlation.

d. Migration patterns.

The occupancy metapopulation model has the advantages of analytical solution and generalizations. It has disadvantages of unrealistic assumptions, difficult parameters, and few or infinitely many patches. The spatially explicit metapopulation model has the advantages of being flexibile and realistic with few implicit assumptions. Its disadvantages are that it is data intensive, difficult to add genetics, and numerical errors may occur. The individual-based metapopulation model has the advantage of being very flexible and realistic. Its disadvantages are that it is easy to make numerical and/or logical errors, is very data intensive, and is sensitive to behavioral assumptions.

Future directions in metapopulation modeling will be in multispecies assessments and in developing community-metapopulation models. In community-metapopulation models, each trophic level would be represented as a metapopulation, each metapopulation would have a different spatial scale, and connections between metapopulations would be based on energy flow.

Ecological risk in an integrated intermedia system

Models and tools are needed to bridge the gap between source, fate, transport, and the resulting ecological impacts. A phased approach is presented for varying levels of detail to match tools to assessment needs. This approach provides for a preliminary as well as a detailed assessment.

The ecological models discussed include the Wildlife Ecological Assessment Program (WEAP), the Ecological Contaminant Exposure Model (ECEM), the Health and Ecological Risk Management and Evaluation System (HERMES), and the Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES).

The WEAP model represents a preliminary assessment to ecological risk analysis. It correlates exposure and effect using laboratory data. It analyzes and correlates concentration and duration of exposure. The model also accounts for frequency of occurrence.

The ECEM model is an ecological risk assessment modeling tool. It estimates exposures from metals, organics, and/or radionuclides in terrestrial and/or aquatic environments. The model is based on a food-web architecture and helps environmental managers assess impacts as part of a regulatory or decision-making process. User inputs for the model are:

a. Contaminants of interest.

b. Species of interest and species in the food web.

c. Environmental data.

Results of the model are:

a. Body burden or dose rate.

b. Compared to environmental benchmarks to calculate the environmental hazard quotient.

c. Can be used as input into human health assessments.

The HERMES model is a flexible visualization and analysis program which helps environmental restoration, land use, and resource managers make decisions. It allows interactive evaluation of impacts with user-selected restoration costs and species values. Other decision dimensions, such as human health, ecological risk, and ecosystem function, can be included as extensions to the model. The advantages of the HERMES model are:

a. Usable - links with user's existing databases.

b. Portable - can be run on a laptop computer, which facilitates public involvement.

c. Easily manipulated - user can control data input values

d. Expandable - modular design allows inclusion of additional decision dimensions.

The FRAMES user interface serves as the integrating platform for all the models discussed. It provides linkages between fate and transport, ecological, and human-health models.

Exposure assessment—Trophic transfer to birds

Why quantify trophic transfer to birds? There are four main reasons which include (1) to computing contaminant levels in species of interest (contaminant levels can be used to assess the potential for toxicity), (2) establishing pathways of contamination, (3) projecting future concentrations, and (4) establishing the potential for effects on population dynamics.

Bioaccumulation can be computed in several ways:

a. Trophic transfer ratios, bioaccumulation factors.

b. Steady-state model.

c. Time-variable simulation model.

BAFs are the simplest, but have the highest degree of uncertainty. The steady-state model is one step above the BAF with the strength of species-specific parameterization, but with the limitation of life-cycle accumulation and temporal changes in exposure sources and levels. Time-variable models have the strength that changes in relative importance of sources can be evaluated and have the limitation that it requires modeling capability and information on parameters. A calibrated model has the strength of reduced uncertainty, but the limitation of requiring site-specific data. Uncertainty analysis for calibrated and uncalibrated models differ. The calibration of a model reduces uncertainty by restricting the parameter sets that are consistent with field measurements.

Technical Issues

Prior to the workshop, a list of questions was generated to aid in focusing the discussions at the workshop. These questions along with the oral presentations provided the background for the Risk Assessment Modeling Workshop. The following questions were used to stimulate discussion at the workshop:

a. What is the state of the art in risk modeling?

b. What are the requirements for a simple- or screening-level risk assessment?

c. What are the requirements for a comprehensive risk assessment?

d. What tools are required for a risk assessment ?

    (1) Exposure component.

    (2) Effects component.

    (3) Other potential components.

    (4) Are these tools applicable for a comprehensive risk assessment, and can the tools be integrated in a common (object oriented) environment?

e. What tools are currently available?

    (1) Exposure component.

    (2) Effects component.

f. Should we develop tools (state-of-the-art) or incorporate existing ones?

g. Is there a need for a risk assessment modeling system/environment? This system would include gains, losses, and advancement of the current state-of-the-art.

h. What is the feasibility of developing a risk assessment modeling system (beyond the current capabilities/state of the art)? Such a system must include structure/platform and output.

i. Can/should the screening-level and comprehensive exposure models coexist in the same modeling environment?

j. Should we develop tie-ins to existing systems (GMS, Surface Modeling System (SMS), and WMS)?

k. What are the existing sources of effects/toxicity databases?

    (1) Public domain.

    (2) File structure (cd, web, binary, bulletin boards, etc.).

    (3) Proprietary

l. What is the desired modeling platform (i.e., personal computer, work \station, web-based . . .)?

2 Summary of Discussions

Introduction

The concepts and foundation for the development of both human and ecological risk assessment have been around for several decades. Past research efforts have yielded methodologies for conducting risk assessments, including exposure and effects assessment, as well as procedures for investigating uncertainty propagation through these models. The basic premise is to calculate risk as a function of both exposure, human or ecological, and effects resulting from exposure. The effects component can be acute or chronic. Therefore, the risk assessment paradigm is typically a problem formulation leading to both an exposure and effects assessment. The combination of the exposure and effect components results in a calculated risk characterization. Risk assessments are useful planning tools for the evaluation and determination of the impact of contaminants on both human and ecological resources.

From a military perspective, the contamination to air, surface water, and groundwater from MRCs has been of increasing concern in the past several years as the result of the closing of munition plants and bases. The assessment of the exposure to ecological units from the many mediums through the use of an exposure model is required to determine the risk associated with exposure to MRCs from these media. This assessment is valuable for permitting and planning activities, as well as for the possible cleanup operations of contaminated sites, should the risk to an ecological unit become too great (Deliman and Gerald 1998).

Background

Historically, there have been several options for conducting risk assessments. Perhaps the simplest of these involves direct field measurements to estimate exposure concentrations. These direct exposure estimates are then compared to effects data to estimate a risk, i.e., a risk quotient. One problem with this method is the assumption that the exposure concentration collected at the sample site is constant, both spatially and temporally. To gain an understanding of the time or

spatial variance influence upon the estimated exposure concentration, a
screening- or comprehensive-level model should be utilized.

Initially, when an indication of the level of risk associated with an exposure is
desired, the use of a screening-level model will maximize the amount of
information provided while minimizing the amount of effort required to obtain
the necessary information to make a risk assessment. A screening-level exposure
model refers to use of simplified, quantitative, predictive methods that minimize
time and effort for implementation. Simplification is achieved by making
assumptions that reduce the complexity of the predictive mathematical
formulations and input data. If the results of the risk estimated by using
screening-level exposure models indicate undesirable risk levels to either human
or ecological resources, a more comprehensive exposure modeling approach
should be employed. Comprehensive models being more physically based, both
spatially and temporally, than the screening-level models can produce results
which are more accurate and defendable. Selection of a comprehensive exposure
model results in increased data and computing resource requirements.

During the workshop, the concept of the platform for the development of
ARAMS was discussed. The three choices that were presented as viable
alternatives were (1) personal computer-based, (2) workstation-based, and
(3)web-based. Of these three, the web-based platform offered the most
advantages, as well as combining the best of PC and workstation environments.
The web-based system design was selected for ARAMS. The primary advantage
of a web-based system is the ability to easily update and maintain databases
which are required for both effect and exposure assessments. Users of ARAMS
can access and search databases via the Internet by launching applets in the
background. In addition, web-based systems offer the advantage of distributed
computing. Distributed computing enables users without high-powered
computing capabilities the option of running programs at remote locations. It is
important to note that some security issues will have to be addressed for access
to secure sites for some military applications.

The ARAMS will be developed for the purpose of conducting both screening-
and comprehensive-level ecological risk assessments. Development of this
system will incorporate current state-of-the-art modeling technologies and will
further utilize concurrent research efforts in the U.S. Army Fate and Effects
Research Program. The ARAMS will be a tool to characterize, integrate, and
estimate ecological risk. The system will provide several tiers of complexity
such that screening-level and complex models issues can be addressed. The
system will include: (a) screening-level assessments based on simple exposure-
response relationships and limited spatial and temporal scales, (b) an expanded
assessment capability based on linkage of more rigorous exposure and ecological
assessment techniques, and (c) linkage of ecological risk, comprehensive
exposure models, and integrated temporal-spatial exposure, i.e., probabilistic
estimate of exposure for individuals/population in time and space.

ARAMS will contain the following components: (a) screening-level models,
(b) comprehensive models, (c) population models, (d) an uncertainty component,
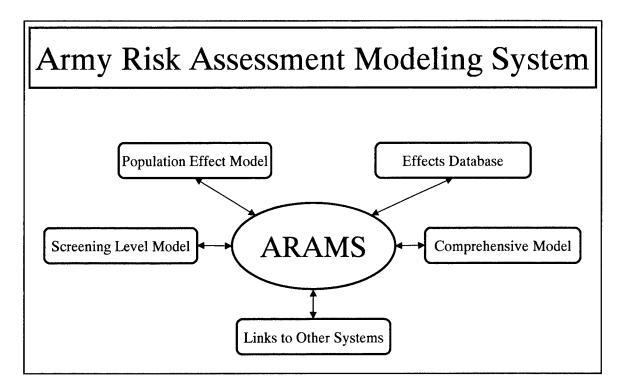
Figure 1. Schematic for the ARAMS

(e) bioaccumulation databases, and (f) effects databases (Figure 1). The uncertainty element will be built into each component of ARAMS. This feature permits users to quantify uncertainty and conduct sensitivity analysis at any point during a simulation. An additional feature of the system is that it will be linked to several systems and legacy codes.

Screening-level model

The screening-level component contained within ARAMS can be used for conducting simple or screening-level risk assessments. Simple risk assessment refers to exposure concentrations estimated from field data while screening level implies that the exposure concentrations are estimated from simple exposure models. Components of the screening-level module include a physico-chemical database, risk calculator, effects database, screening-level exposure models, and linkages to other fate and transport exposure models (Figure 2). To accomplish this objective, the workshop participants recommended the incorporation of FRAMES as the platform for the screening-level model (Whelan et al. 1999).

FRAMES was developed by Pacific Northwest National Laboratory for the DoE. FRAMES is an object-oriented model that is still under development. Within FRAMES will reside a collection of computer algorithms that will simulate the following elements of a transport, exposure, and risk assessment system: contaminant source and release to environment (including surface hydrology), overland flow transport, vadose-zone transport, food-supply

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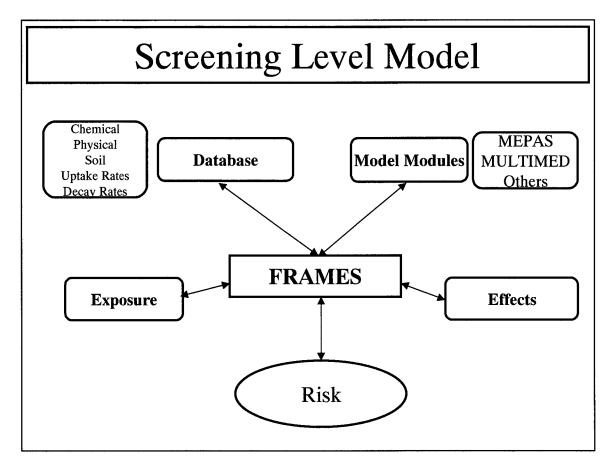
Figure 2. Screening-level model

transport (including animals and plants to humans), intake computation, and health impacts.

The database contained within the screening-level model provides chemical and physical properties, uptake and decay rates, as well as a soil properties characterization tool for input into the exposure modules. The exposure models currently contained within FRAMES are those developed for the Multimedia Environmental Pollutant Assessment System (MEPAS) and Multimedia Exposure Assessment Model (MULTIMED) (Buck et al. 1995, Salhotra et al. 1993).

The human health exposure components include the exposure pathways, the intake routes, and the human health effects database (IRIS and HEAT (Whelan et al. 1999)) containing noncarcinogenic and carcinogenic chemicals as well as radionuclides.

Models that will be included into FRAMES in the near future are RECOVERY and the Hydrologic Evaluation of Landfill Performance (HELP). RECOVERY is a sediment water interaction model to assess the impact of toxicants in the aquatic environment (Boyer et al. 1994). HELP is a landfill modeling tool to assess the movement of contaminants through contaminated

soils and dredge material (Schroeder et al. 1994). It can be applied to evaluate landfill performance.

Comprehensive model

Similar to the screening-level model, the comprehensive model will have access to databases for physcio-chemical properties. The primary difference is that the comprehensive model (CE-QUAL-ICM/TOXI) (Wang et al. in preparation) can account for spatial and temporal variance in exposure estimation (Figure 3). Processes within the comprehensive model include chemical and solids transport in the water column and sediment bed, sorption to dissolved organic matter and three solids (sand, silt, and clay), chemical and biological degradation, and volatilization (Wang et al. in preparation). In addition, modules for addressing trophic transfer, bioaccumulation, and bioconcentration of contaminants will be available.
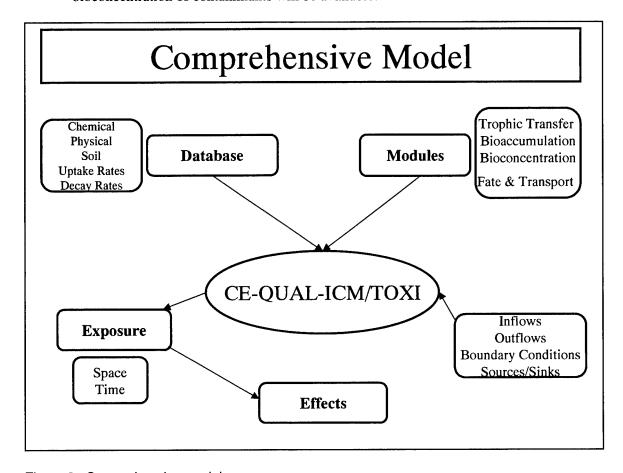
Figure 3. Comprehensive model

CE-QUAL-ICM/TOXI (Wang et al. in preparation) must be linked to comprehensive hydrodynamics codes such as CH3D and RMA10 (Environmental Modeling Research Laboratory 1998b) that compute the input required to run the water quality and contaminant transport model. In addition,

the user has to provide extensive input relating to contaminant boundary
conditions, sources and sinks, and contaminant inflows and outflows.

The model produces exposure concentrations in the water column and
sediment bed over time and space (one-, two-, or three-dimensional (1-D, 2-D,
3-D)). This information can be exported to other ARAMS modules or can be
coupled with the effects database to estimate a comprehensive human or
ecological risk assessment.

Population-effect model (PEM)

Population-effect models will be included in ARAMS to estimate the risk to
single organisms, populations, and ecosystems. Both aquatic and terrestrial
effects components will be incorporated. The first step is the determination of
the effect on a single organism. Once this is achieved, the population models
can be utilized to estimate the overall effect on a given population. For example,
effects that can be seen in the environment can correspond to reduction in
fertility, survival of young and adults, and susceptibility to predation. Initially,
the metapopulation effect models included in ARAMS will be for an estuarine
amphipod and a marine polychaete (Figure 4). The coupling of these and other
metapopulation modules will allow for an evaluation of the interactions of
population groups and the effect of contaminant exposure within a given
population, resulting in an ecological risk assessment.
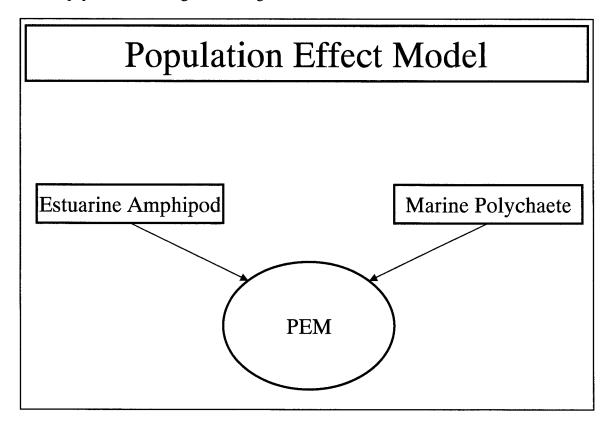
Figure 4. Population-effect model

Another component of the population-effect model will be the incorporation of food chains or food webs. This feature will allow for the evaluation of trophic transfers of contaminants in the ecosystem. Coupling these population effects models with the exposure data predicted from the comprehensive models will provide a comprehensive environmental risk assessment.

Effects database

An integral part of any risk assessment modeling system is the effects database. The effects database provides the relationship between the exposure concentration and the effects to individual organisms. The effects database in ARAMS will contain the Environmental Residue-Effects Database (ERED) and the Biota-Sediment Factor Database (BASF) (Figure 5). ERED is a compilation of literature data where both biological effects and tissue contaminant concentration were simultaneously measured in the same organism. Biological effects refer to a measured or observed effect such as reduced survival, growth, reproduction, etc. Currently, the biological effects within an organism are limited to those linked to specific contaminants observed in the tissue.

Effects Database

> 200 Chemical Compounds

2000 Toxicity Records

ERED
(Environmental Residue-Effects Database)

Queried Data - Tabular or Graphic

Queries - Species, Chemical, etc.
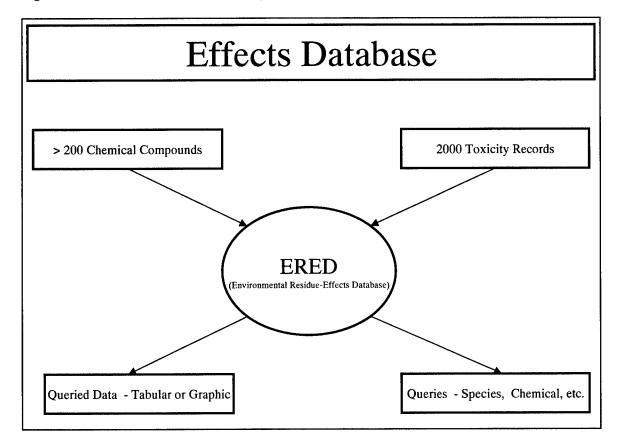
Figure 5. Effects database

The ERED database contains some organism bioaccumulation data, although bioaccumulation is a measurable phenomena rather than an effect. The measured or predicted level due to bioaccumulation is not sufficient information to conclude that the contaminant will produce an adverse effect. The key is to compare the level due to bioaccumulation to a measurable biological effect like those in the ERED database.

The BASF database is a collection of laboratory and field generated BASF numbers. The database also contains lipid values for numerous organisms which can be used in lieu of actual organism lipid content. BASF numbers are used to predict more environmentally realistic bioaccumulation levels when using the Thermodynamic Bioaccumulation Potential (TBP) formulation. The TBP estimates the bioaccumulation potential directly from the contaminant sediment concentration, organism lipid content, contaminant BASF, and sediment organic carbon.

Links to other systems

Based on workshop consensus, it was decided that the ARAMS would provide links and hooks to access legacy codes and other modeling systems. This component of ARAMS maximizes the use of existing codes with minor development of linkages. Linkages will be developed for transferring input and output between the modules and/or components. Initially, systems that will be linked into the ARAMS will include the three DoD modeling systems which provide a comprehensive graphical user environment (Figure 6). All three DoD modeling systems can be characterized as comprehensive components of ARAMS.

The WMS is used for performing hydrologic and water quality analysis and supports several legacy codes including HEC1, TR-55, CASC2D, and HSPF (Environmental Modeling Research Laboratory 1998a). These models represent both widely used lumped parameter models, as well as more advanced 2-D distributed parameter watershed models. Models contained in the WMS can be used to address the terrestrial component for exposure assessments.

The GMS is used for performing groundwater simulations, site characterizations, model conceptualizations, and geostatistical interpretation (Environmental Modeling Research Laboratory 1999). GMS supports several legacy codes including MODFLOW, FEMWATER, MT3D, RT3D, and SEAM3D. These models represent more advanced 3-D water and contaminant transport models for exposure for human (drinking wells) and ecological exposure (groundwater-surface water interactions). Models contained in the GMS can be used to address the groundwater component for exposure assessments.

The SMS is used for performing model conceptualization, mesh generation, statistical interpretation, and visual examination of surface water model
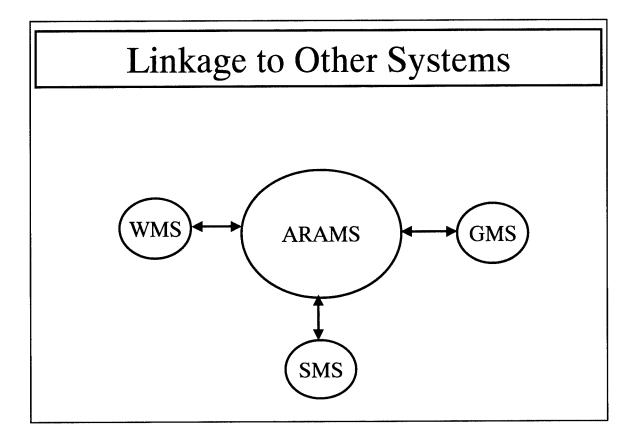
Figure 6. Linkage of ARAMS to existing comprehensive modeling systems

simulations (Environmental Modeling Research Laboratory 1998b). SMS supports several hydrodynamics and water quality legacy codes including RMA10, TABS-MD, CH3D, and CEWES-ICM (Wang et al. in preparation). Models contained in the SMS can be used to address the aquatic component for exposure assessments including both water column and bottom sediments.

Future efforts will include linkage of additional legacy codes from the EPA, USGS, DoE, and universities. The ARAMS flexible design will allow implementation of other systems and legacy codes without the burden of maintenance. This is accomplished through the ARAMS by providing only the linkage to these systems. Code maintenance will be the responsibility of the owners of the legacy codes and modeling systems.

3 Workshop Recommendations

During the workshop a list of system attributes was developed for ARAMS. The list was made in an effort to provide a flexible framework that would allow for adaptation of emerging technologies as well as provide the users seamless access to databases contained at web-site locations. For ARAMS to be successful, the consensus was that the following points would have to be addressed by the system:

- Web-Based, Network Services

- Ecologically Oriented and Spatially Explicit

- Contains Components for Both Human & Ecological Risk

- Standard Hooks Between Models

- Integration of Legacy Models

- Modular to Include New Models, Science

- Couples Exposure, Fate, Effects, Uncertainty, Economics - Risk vs Cost

- Launches Off User's Desktop, Probably in Windows NT, Supports UNIX, PCs

- Transport Use if Used for High Performance Computing (HPC)

- Data Standards to Allow as Seamless as Possible Data Access

- Client/Server Relationships to Access Remote Data, Simulations

- Multimedia from Outset

- Differing Levels of Tools From Screening to HPC

- Leverage Funding from Other Federal Sources

- Self Defensive Software - Units, Range Checking

- Security "Black Box" - For Certain Military Applications

- Smart - Adaptive Software

The development of ARAMS is anticipated to take several years to complete. One last major point discussed at the workshop was the necessity of choosing a proper location to test the system. A site would have to be chosen with a plethora of data such that screening- and comprehensive-level approaches for risk assessment for both ecological and human risk could be validated.

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Appendix A
Conference Agenda and List of Participants

Conference Agenda

Risk Assessment Modeling Workshop
Final Agenda

May 14, 1998

07:30 - 08:30   *Registration*

08:30 - 08:40   *Introduction to the Risk Assessment Modeling Workshop*
Patrick N. Deliman - U.S. Army Engineer Waterways
Experiment Station

08:40 - 08:50   *Fate & Effects Modeling Concepts*
Richard E. Price - U.S. Army Engineer Waterways Experiment
Station

08:50 - 09:00   *Ecological Risk Assessment Concepts*
Todd Bridges - U.S. Army Engineer Waterways Experiment
Station

09:00 - 09:45   *Deployment Exposure Surveillance System*
Jack Heller and William Legg -
U.S. Army Center for Health Promotion & Preventive
Medicine

09:45 - 10:15   *WEB Based Approach for Developing Risk Assessment
Modeling System*
Jeffery Holland - U.S. Army Engineer Waterways Experiment
Station

10:15 - 10:30	BREAK
10:30 - 11:00	*Groundwater Modeling System (GMS)* Jeffery Holland - U.S. Army Engineer Waterways Experiment Station
11:00 - 11:30	*The Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES)* Gene Whelan - Battelle Pacific Northwest National Laboratory
11:30 - 12:00	*Dredged Material Modeling - Risk Based Concepts* Paul Schroeder - U.S. Army Engineer Waterways Experiment Station
12:00 - 13:30	LUNCH
13:30 - 14:00	*Bioaccumulation Modeling Concepts and Principles/Contemporary Issues* Bob Thomann - Manhattan College
14:00 - 14:30	*Ecosystem Models for Ecological Risk Analysis: From Single Species to Communities* Scott Ferson - Applied Biomathematics
14:30 - 15:00	*You Don't Need to Know A Lot of Ecology to Make a Comprehensive Ecological Risk Assessment* Scott Ferson - Applied Biomathematics
15:00 - 15:30	BREAK
15:30 - 16:00	*Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model* Bill Mills - TETRA TECH, INC.
16:00 - 16:30	*Metapopulation Models and Ecological Risk Analysis: A Habitat-based Approach to Biodiversity* H. Resit Akcakaya - Applied Biomathematics
16:30 - 17:00	*Ecological Risk in an Integrated Intermedia System* Gene Whelan - Battelle Pacific Northwest National Laboratory
17:00 - 17:30	*Exposure Assessment - Trophic Transfer to Birds* David Glaser - Quantitative Environmental Analysis
18:30 - 20:00	COMPUTER SOFTWARE DEMONSTRATIONS

May 15, 1998

08:00 - 10:00	*Discussion of Risk Assessment Modeling Concepts for Military Needs* Carlos E. Ruiz - U.S. Army Engineer Waterways Experiment Station
10:00 - 10:30	BREAK
10:30 - 12:00	*Discussion Continued*
12:00 - 13:30	LUNCH
13:30 - 15:00	*Workshop Summary & Conclusions*
15:00 - 15:30	*Adjourn*

List of Participants

Risk Assessment Modeling Workshop
May 14-15th 1998

Name:	Affiliation:
H. Resit Akcakaya	Applied Biomathematics
Dennis L. Brandon	U.S. Army Corps of Engineers - WES
Jim Brannon	U.S. Army Corps of Engineers - WES
Todd Bridges	U.S. Army Corps of Engineers - WES
Patrick N. Deliman	U.S. Army Corps of Engineers - WES
Val Emery	U.S. Army Corps of Engineers - WES
Scott Ferson	Applied Biomathematics
Jeff Gerald	AscI, Inc.
David Glaser	Quantitative Environmental Analysis, LLC.
Jeff Holland	U.S. Army Corps of Engineers - WES
Mark S. Johnson	U.S. Army Center for Health Promotion & Preventive - CHPPM
Glenn Leach	U.S. Army Center for Health Promotion & Preventive - CHPPM
William E. Legg	U.S. Army Center for Health Promotion & Preventive - CHPPM
Bill Mills	Tetra Tech. Inc.
Richard E. Price	U.S. Army Corps of Engineers - WES
Carlos E. Ruiz	U.S. Army Corps of Engineers - WES
Toni Schneider	U.S. Army Corps of Engineers - WES
Paul Schroeder	U.S. Army Corps of Engineers - WES
Larry Tannenbaum	U.S. Army Center for Health Promotion & Preventive - CHPPM
Robert V. Thomann	Manhattan College
Gene Whelan	Pacific Northwest National Laboratory

Appendix B
Ecological Risk Assessment Concepts

This appendix contains the presentation documents for "Ecological Risk Assessment Concepts" by Todd Bridges - U.S. Army Engineer Waterways Experiment Station.

Ecological Risk Assessment

```
                  ┌─────────────────────┐
                  │ Problem Formulation  │
                  └─────────────────────┘
                             │
                             ▼
┌─────────────────────┐           ┌─────────────────────┐
│ Exposure Assessment │           │ Effects Assessment  │
└─────────────────────┘           └─────────────────────┘
                             │
                             ▼
                  ┌─────────────────────┐
                  │ Risk Characterization│
                  └─────────────────────┘
```

DoD and Risk Assessment

- Historical emphasis on human health protection
- Ecological concerns are becoming more prominent

DoD and Risk Assessment

- ERA survey of 190 Army facilities
  - >50% were/anticipated conducting ERA
  - Average estimated ERA cost $1,000K
  - Average per projected eco-based cleanup costs, $500K-$6,000K
  - Ecological concerns resulted in programmatic delays of 3 mos to 2 yrs

DoD Risk Assessment <u>Needs</u>

- Modeling/software tools for risk characterization
  - Currently, detailed exposure information is ineffectively combined with effects information
    - Effects information poorly organized
    - Hazard quotients are inefficient

DoD Risk Assessment <u>Needs</u>

- Modeling/software tools for projecting effects beyond individual organisms
  - Human health model generally inappropriate for assessing ecological risk
  - Concern should be focused on higher order effects
    - "Toxic substances have effects at the level of cellular biochemistry, but their ecological consequences are at the levels of the population, community, and ecosystem. Thus, there is a translation problem at the core of ecotoxicology: how to translate mechanisms at one level into effects at another." Caswell, 1996

DoD Risk Assessment <u>Needs</u>

Modeling/software tools for incorporating spatial and temporal issues when assessing risk

- Space is a primary resource and key determinate of exposure
  - "The absence of space as a dimension in ecotoxicological risk assessment seems puzzling upon reflection... Spatially explicit risk assessment is limited largely by the available effects models. The organism, population, and ecosystem effects models currently in use nearly always assume homogeneous exposure and responses." Suter, 1993.
- The risk today is not the risk tomorrow

DoD Risk Assessment Needs

- Modeling/software tools for quantifying uncertainties
  - Variation dominates ecological systems
  - Risk is the probability of an adverse event
  - "If a man will begin with certainties, he shall end in doubts; but if he will be content to begin with doubts, he shall end in certainties."
    Francis Bacon, 1561-1626
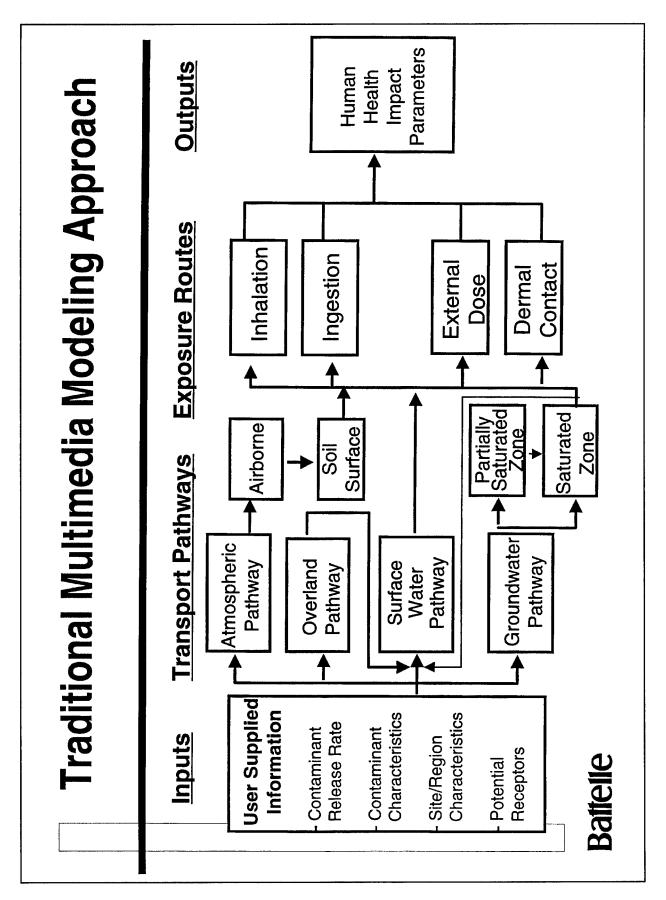
Appendix C
Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES)
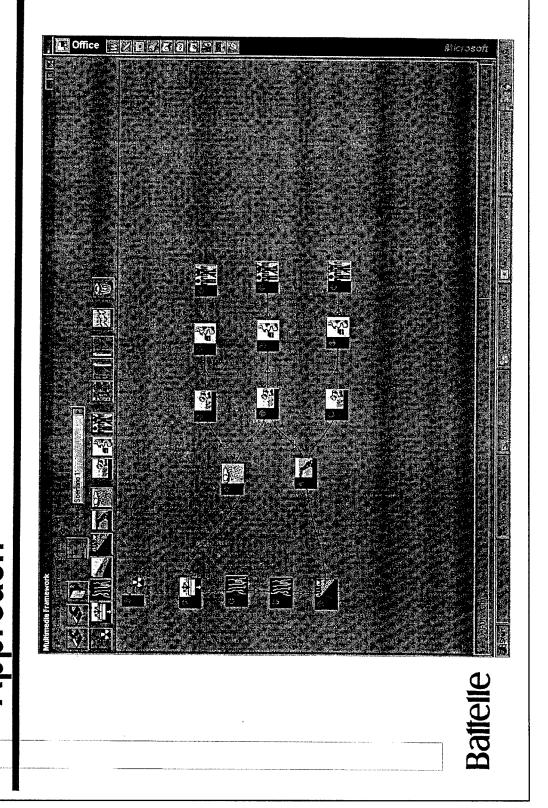
This appendix contains the presentation documents for "The Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES)" by Gene Whelan - Battelle Pacific Northwest National Laboratory.
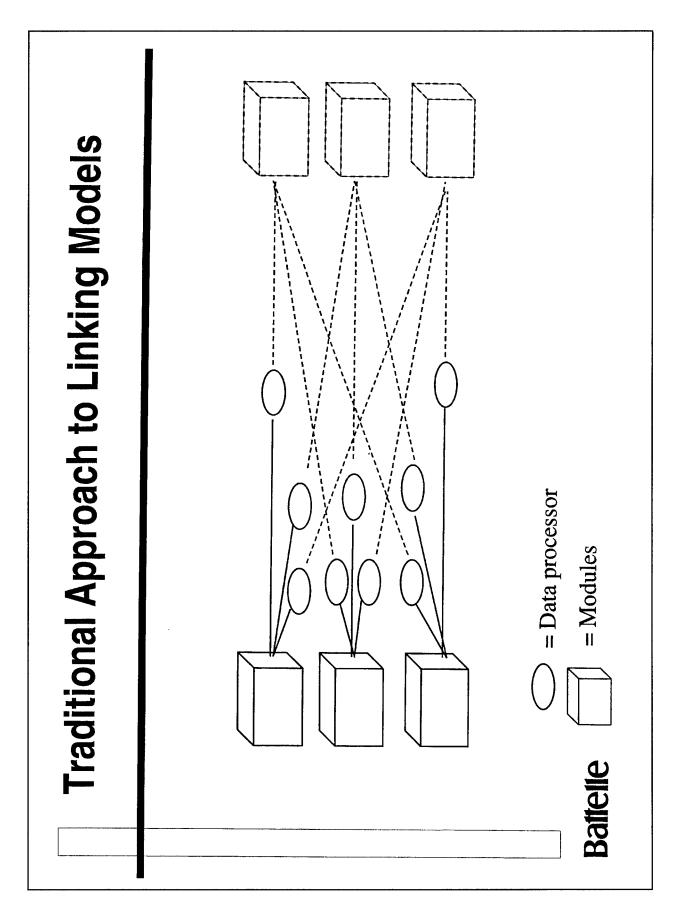
Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES)

Gene Whelan, Ph.D

Pacific Northwest National Laboratory

Richland, Washington
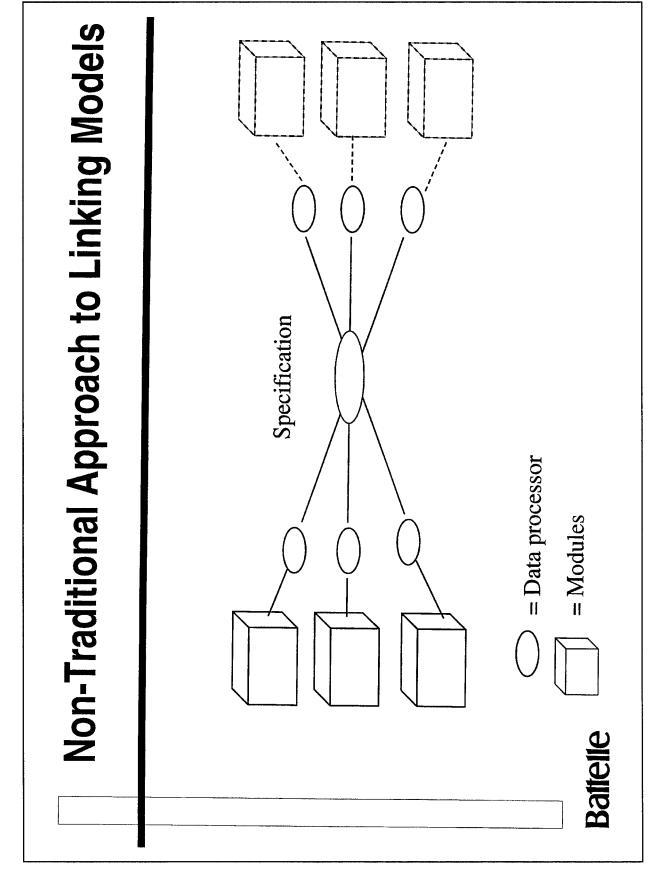
Battelle

FRAMES

- FRAMES is a software platform that allows models, developed by different people, to link and communicate with each other, while maintaining the legacy of the originals models.

Battelle

Traditional Multimedia Modeling Approach

Inputs   **Transport Pathways**   **Exposure Routes**   **Outputs**

User Supplied Information

- Contaminant Release Rate
- Contaminant Characteristics
- Site/Region Characteristics
- Potential Receptors

Atmospheric Pathway

Overland Pathway

Surface Water Pathway

Groundwater Pathway

Airborne

Soil Surface

Partially Saturated Zone

Saturated Zone

Inhalation

Ingestion

External Dose

Dermal Contact

Human Health Impact Parameters

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Non-Traditional Multimedia Modeling Approach

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Traditional Approach to Linking Models

○ = Data processor

▱ = Modules

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Non-Traditional Approach to Linking Models

Specification

◯ = Data processor

▢ = Modules

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Purpose of Framework

- ■ View all models as common objects
- ■ Provide common data specifications for suite of objects
- ■ Require minimal modifications to models
- ■ Link to other framework environments

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FRAMES Structure

Framework User Interface

Global Input Files · Global Output Files

Link to other Framework

Air Transport Module
Source Term Module
Vadose Zone Module
Saturated Zone Module
Surface Water Module
Exposure Module
Dose Module
Health Impacts Module

Implementation of Module

Matrix Correlating Mesh Resolution with Scaling Dependency

	SCALE			
	MEDIUM SPECIFIC	WATERSHED	REGIONAL	GLOBAL
RESOLUTION — LOW				
RESOLUTION — MEDIUM				
RESOLUTION — HIGH				

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Matrix Correlating Mesh Resolution with Scaling Dependency

RESOLUTION	SCALE			
	MEDIUM SPECIFIC	WATERSHED	REGIONAL	GLOBAL
LOW				
MEDIUM				
HIGH				

Battelle

Example

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Appendix C   Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES)

Summary

- Allows users to implement preferred models
- Allows users to link preferred models to and communicate with other models
- Allows for a standard, base set of models (Regulatory Review)
- Maintains Legacy of models
- Provides a "plug-and-play" environment
- Helps the user with the conceptual site model

Battelle

Appendix D
Dredged Material Modeling—Risk-Based Concepts

This appendix contains the presentation documents for "Dredged Material Modeling—Risk-Based Concepts" by Paul Schroeder - U.S. Army Engineer Waterways Experiment Station.

Dredged Material Modeling -- Risk Concepts

Paul R. Schroeder

Environmental Laboratory

USAE Waterways Experiment Station

Introduction

- Technical evaluation of the environmental acceptability of dredged material disposal is an effects-based process compatible with risk assessment.

- Computer programs and databases have been developed to aid in the evaluation:

  - ADDAMS

  - DANNY (Open water disposal data acquisition network and management tools/models)

  - E2D2

Technical Framework

- Effects testing coupled with pathway modeling to predict exposure
  - ◆ Upland Disposal
    - ✦ Effluent
    - ✦ Runoff
    - ✦ Leachate
    - ✦ Volatilization
    - ✦ Plant uptake
    - ✦ Animal uptake
  - ◆ Open Water
    - ✦ Water column
    - ✦ Benthic

- Multi-tiered, screening level to ....
- Comparison of exposure with toxicity criteria or effect level instead of risk computation

Topics of Discussion

■ USCOE/USEPA Technical Framework

■ ADDAMS and E2D2

■ User Needs

ADDAMS (Automated Dredging and Disposal Alternatives Modeling System)

- PC-based system for DOS and Windows 95
- Collection of simple, nonintegrated, computerized tools and models for dredged material management and environmental effects evaluations
- Collection of 16 modules
- Predominantly stand-alone screening-level models linked under a common shell or menu
- Hardware and operating platform requirements restricted to availability of the masses (lowest common demoninator)

Example ADDAMS Application

Evaluation of Effluent Pathway from an Upland Confined Disposal Facility CDF--

- **DYECON** module to estimate CDF hydraulic efficiency

- **SETTLE** to analyze settling test data to estimate effluent suspended solids concentration using hydraulic efficiency

- **EFQUAL** to analyze modified elutriate test data to estimate effluent quality using effluent suspended solids and to compare with water quality criteria and predict dilution requirements

- **LAT-E** to analyze water column bioassay test data to estimate toxicity to compare with toxicity quality criteria and predict dilution requirements

- **CDFATE** to compute mixing zone size using dilution requirements

E2D2 (Environmental Effects Determination Database)
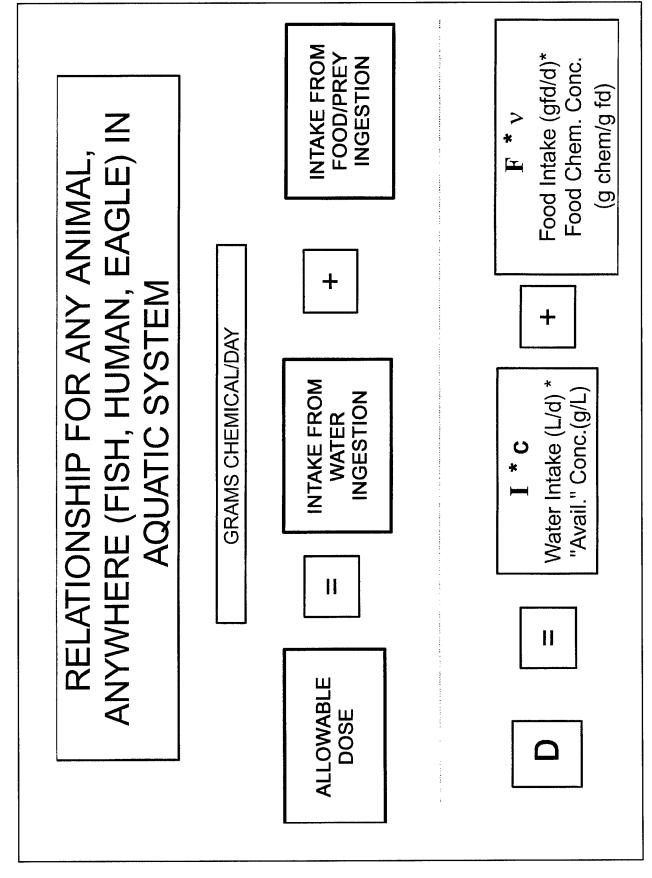
- Web based database of literature on environmental effects of contaminant residue in tissue of aquatic organisms

- Interpretation of bioaccumulation data to determine environmental significance in absence of criteria

User Needs

- Multi-tier
- Models of control measures and operational restrictions
- Common, consistent, simple user interface
- Data bases
- Documentation, support, and training
- Verification, validation, and endorsement
- Portability
- Easy access

Appendix E
Bioaccumulation Modeling Concepts and Principles/Contemporary Issues

This appendix contains the presentation documents for "Bioaccumulation Modeling Concepts and Principles/Contemporary Issues" by Bob Thomann - Manhattan College. Complete information for references cited in this appendix was provided in handouts at the time of the workshop.

RELATIONSHIP FOR ANY ANIMAL, ANYWHERE (FISH, HUMAN, EAGLE) IN AQUATIC SYSTEM

GRAMS CHEMICAL/DAY

ALLOWABLE DOSE

=

INTAKE FROM WATER INGESTION

+

INTAKE FROM FOOD/PREY INGESTION

D

=

I * c

Water Intake (L/d) *
"Avail." Conc.(g/L)

+

F * v

Food Intake (gfd/d)*
Food Chem. Conc.
(g chem/g fd)

FOR WATER QUALITY CRITERIA:

NEED A RELATIONSHIP BETWEEN CHEMICAL CONCENTRATION IN FOOD (PREY) AND CHEMICAL CONCENTRATION IN WATER

INITIALLY

ASSUMED FOOD CHAIN BIOACCUMULATION OF CHEMICAL WAS NOT SIGNIFICANT

DEFINE BIOCONCENTRATION FACTOR (BCF) AS RATIO CHEMICAL CONC. IN FOOD TO WATER CONC. <u>FOR EXPOSURE TO WATER ONLY</u>

MAJOR ADVANTAGES

1. BCF EASILY DETERMINED IN LABORATORY UNDER CONTROLLED CONDITIONS WITH "STANDARD" (SMALL) FISH

2. NOT DEPENDENT ON SITE CHARACTERISTICS

THEN THE WATER QUALITY CRITERION IS :

WQC:
c(allow)

$$= \frac{D(allow)}{(I + F*BCF)}$$

D(allow): from Dose/Response,
I & F: from general intake/consumption data
BCF: from lab experiments

NEAT & CLEAN

SITE INDEPENDENT
NATIONAL WQC POSSIBLE

WASTE
LOAD
ALLOCATION

WASTE LOAD
ALLOCATION:
SITE DEPENDENT

PHYSIO-CHEMICAL
FATE/TRANSPORT
MODEL:
DILUTION,
PARTITIONING,
BIOAVAILABILITY,
KINETICS

WQC:
c(allow)

CRITERIA:
SITE
INDEPENDENT

NOW THE WATER QUALITY CRITERION IS :

$$WQC: c(allow) = \frac{D(allow)}{(I + F*BAF)}$$

BAF IS DEPENDENT ON FOOD WEB

NOT SO NEAT & CLEAN
MORE SITE DEPENDENT
NATIONAL WQC POSSIBLE ONLY
FOR GENERIC FOOD WEB
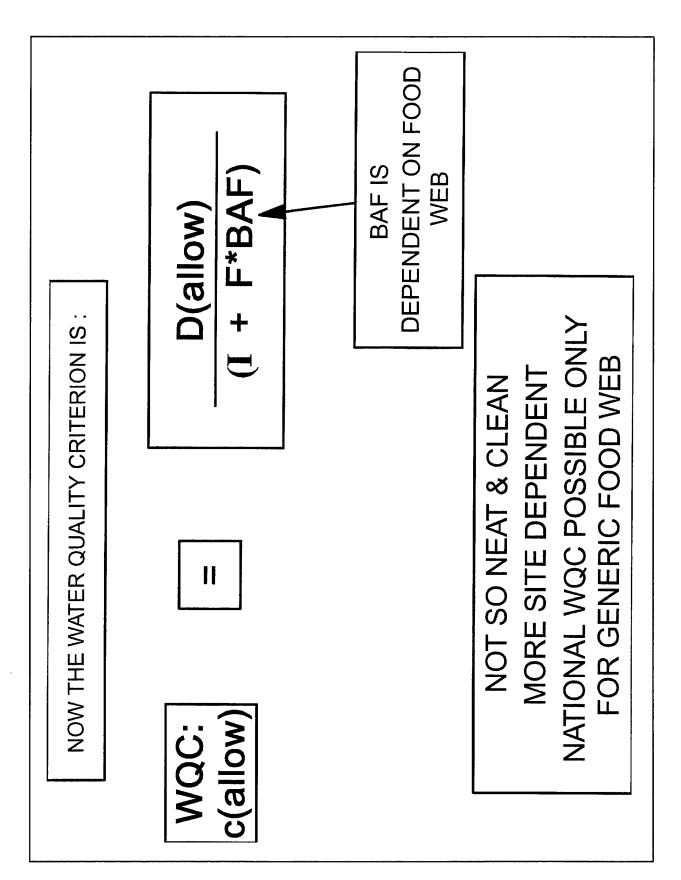
PHYSIO-CHEMICAL
FATE/TRANSPORT
MODEL:
DILUTION,
PARTITIONING,
BIOAVAILABILITY,
KINETICS

WASTE
LOAD
ALLOCATION

FOOD WEB
MODEL:
UPTAKE,
INGESTION,
DEPURATION,
METABOLISM

WASTE LOAD
ALLOCATION:
SITE DEPENDENT

FRC:
Allow.
Food
Conc.

CRITERIA:
SITE
INDEPENDENT

HOW TO DETERMINE ALLOWABLE WASTE LOAD ALLOCATION OF CHEMICALS THAT MAY BIOACCUMULATE?

- ## ISSUE

  - **Time Variable** Load, Flow= time variable Water & Sediment Conc. = time variable Organism Tissue Conc.

  - **Bioaccumulation Factor (BAF)**

    = Tissue (t)/Water (t);

    useful for **Steady State** or slowly varying evaluations.

PROPOSED APPROACH

- REGULATE ON ALLOWABLE TISSUE CONCENTRATION @ ASSIGNED FREQUENCY OF EXCEEDANCE PERCENTILE

- DETERMINE ALLOWABLE FREQUENCY DISTRIBUTION OF CHEMICAL INPUT LOAD

THE PROBLEM CONTEXT

TIME VARIABLE INPUT CHEMICAL LOAD (kg/d)

TIME - DAYS

0   180   360   540   720

RIVER

PLAN VIEW

TIME VARIABLE RIVER FLOW (m³/s)

TIME - DAYS

0   180   360   540   720

Appendix E   Bioaccumulation Modeling Concepts and Principles/Contemporary Issues

A SIMPLE THREE-LEVEL FOOD CHAIN

Level #3
Large Fish 1000 gm

Level #2
Small Fish 10gm

Level #1
Food for
Small Fish

Available
Water Conc.

Sediment
Conc.

LEVEL #3 - LARGE FISH

LARGE FISH BIOACCUMULATION FACTOR

WATER CONCENTRATION

LOG K_{ow} = 6.0

CONSTANT RIVER FLOW

CONSTANT INPUT LOAD

UPTAKE FROM WATER ONLY

LEVEL #3 - LARGE FISH

LARGE FISH BIOACCUMULATION FACTOR

WATER CONCENTRATION

LOG K$_{ow}$ = 6.0

VARIABLE RIVER FLOW

CONSTANT INPUT LOAD

UPTAKE FROM WATER ONLY

LEVEL #3 - LARGE FISH

LARGE FISH BIOACCUMULATION FACTOR

WATER CONCENTRATION

LOG K_{ow} = 6.0
VARIABLE RIVER FLOW
VARIABLE INPUT LOAD
UPTAKE FROM WATER ONLY

LEVEL #3 - LARGE FISH

LARGE FISH
BIOACCUMULATION FACTOR

WATER CONCENTRATIO

LOG K$_{ow}$ = 6.0

VARIABLE RIVER FLOW

CONSTANT INPUT LOAD

UPTAKE FROM WATER ONLY

UPTAKE & DEPURATION FROM FOOD

IUPAC #136 (Data from Sijm 1992)

8 YEAR DEPURATION OF PCB IN EELS
TRANSFERRED TO "CLEAN" LAKE

(Data from de Boer et al. 1994)

Appendix E   Bioaccumulation Modeling Concepts and Principles/Contemporary Issues

Pentachlorobiphenyl (2,2',3,4',5')
Rainbow Trout, Data: Niimi & Oliver (1983)

UPTAKE & DEPURATION OF TISSUE PCB (2,2',4,4',5,5')
IN JUVENILE COHO SALMON
(Data from Gruger et al. 1975)

CADMIUM UPTAKE & DEPURATION
DATA: HARRISON & KLAVERKAMP 1989

WHOLE FISH
Rainbow Trout &
Lake Whitefish

CADMIUM UPTAKE & DEPURATION
DATA: HARRISON & KLAVERKAMP 1989

KIDNEY
Rainbow Trout &
Lake Whitefish

UPTAKE

DEPURATION

DAYS EXPOSURE

CADMIUM MASS (PG)
Thousands

A SEVEN-COMPARTMENT FISH MODEL FOR CADMIUM UPTAKE & DEPURATION

COMPARISON OF 7-COMPARTMENT MODEL TO
KIDNEY CADMIUM BODY BURDEN

A SIMPLE THREE-COMPARTMENT MODEL

"STORAGE"

STORAGE EXCHANGE

"READILY PERFUSED"

GUT EXCHANGE

GUT

EGESTION

AQUEOUS EXCHANGE

METABOLISM

FOOD INGESTION

THREE-COMPARTMENT MODEL
IUPAC #136 (Data from Sijm 1992)

Figure 1. Comparison of original (as corrected) model projection (solid line) made in 1987 to observed data of striped bass (2-5 yr old), Food Web Region #2

Figure 2. Comparison of observed *vs.* Model exceedance frequencies (%=< 2 ug/g). Striped bass (2-5 yr old), Food Web Region #2

Figure 3. Variation in total PCB concentration in striped bass (2-5 yr old), Food Web Region #2. Line in box = 50th %tile, box boundaries = 25th and 75th %tile, symbols = outliers

Figure 4. Calculated effect of varying migration of striped bass (2-5 yr old), Food Web Region #2
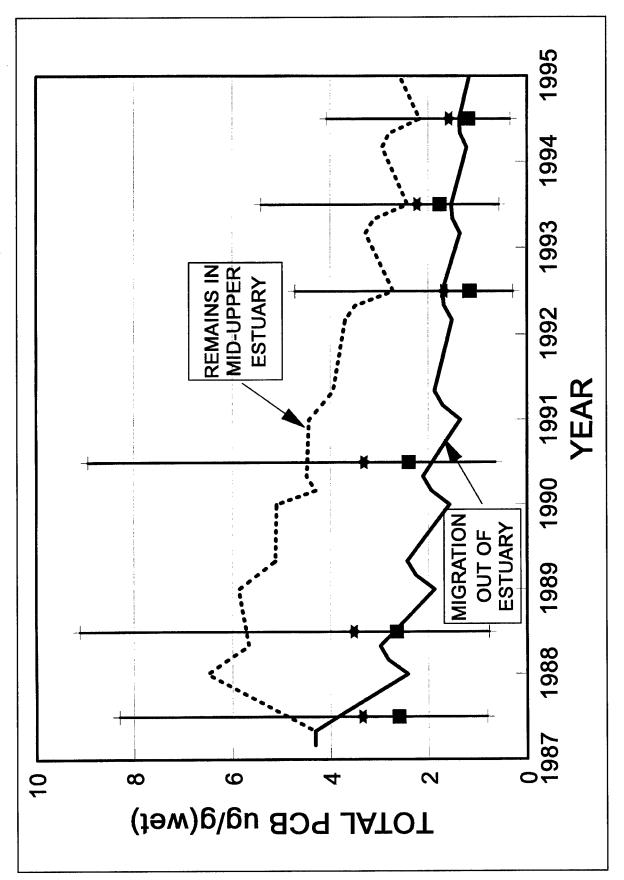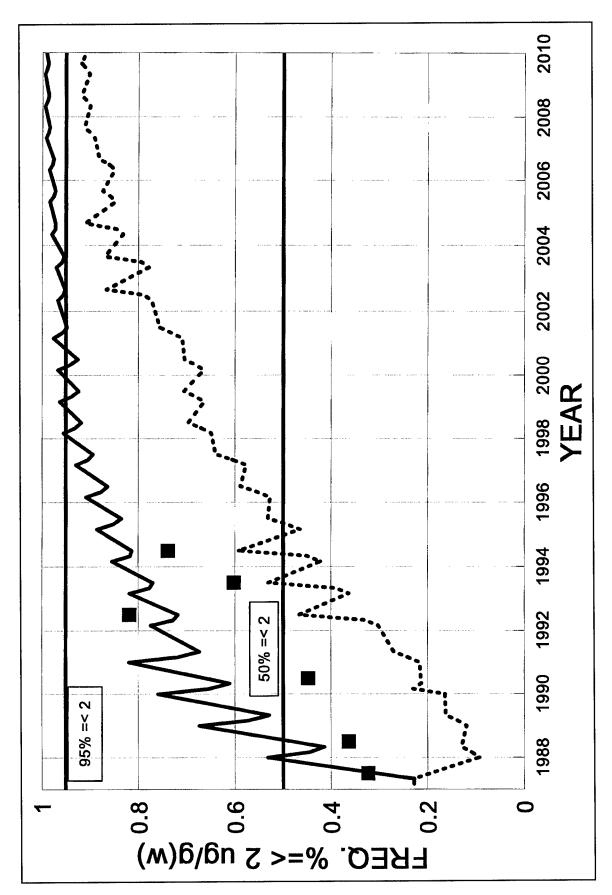
Appendix E   Bioaccumulation Modeling Concepts and Principles/Contemporary Issues

Figure 5. Long term model projection using original (1987) load projections with varying migration by striped bass. Solid line: striped bass migrates out of estuary; dashed line fish remains in estuary. Striped bass (2-5 yr old), Food Web Region #2

Figure 6.   Long term model projection of frequency of striped bass =< 2 ug/g with varying migration by striped bass. Solid line: striped bass migrates out of estuary; dashed line: fish remains in estuary. Striped bass (2-5 yr old), Food Web Region #2

Appendix F
Ecosystem Models for Ecological Risk Analysis: From Single Species to Communities

This appendix contains the presentation documents for "Ecosystem Models for Ecological Risk Analysis: From Single Species to Communities" by Scott Ferson - Applied Biomathematics.

Adding Ecology to Ecotoxicology

Scott Ferson
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Acknowledgments
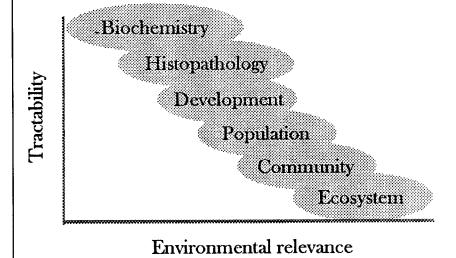
Abstract

To justify regulatory and mitigation decisions, toxicologists are often asked the "so what?" questions that demand predictions about the population or even ecosystem response to contamination. RAMAS Ecotoxicology is microcomputer software specifically created to assist toxicologists answer such questions by extrapolating effects on organisms observed in bioassays to their eventual population-level consequences. It provides a software shell from which users can construct their own models for projecting toxicity effects through the complex filters of demography, density dependence and ecological interactions in food chains. It allows various standard choices about low-dose response models (probit, etc.), which vital parameters are affected by the toxicant, the magnitudes and variabilities of these impacts, and species-specific life history descriptions. During the calculations, the software distinguishes between measurement error and stochastic variability. It forecasts the expected risks of population declines resulting from toxicity of the contaminant and provides estimates of the reliability of these expectations in the face of empirical uncertainty. This risk-analytic endpoint is a natural summary that integrates disparate impacts on biological functions over many organizational levels. Where applicable, the software automatically performs consistency tests to check that the input conforms to statistical assumptions and is dimensionally coherent. Parameterizations have already been prepared for several vertebrate and invertebrate species for use in assessments of soil or sediment contamination.

Impacts propagate through hierarchy

Incompleteness of bioassays

- Chooses endpoints arbitrarily
- Treats each insult separately
- Focuses on individuals
- Cannot answer 'So what?' questions

Despite the scientific difficulty, we need to increase environmental relevance of the assessments we make.

Why ecology *matters*

1) Cascade of impacts
2) Conflicting effects
3) Temporally lagged effects
4) Compensatory phenomena
5) Counterintuitive results
6) Indirect ecological effects

Cascade of impacts
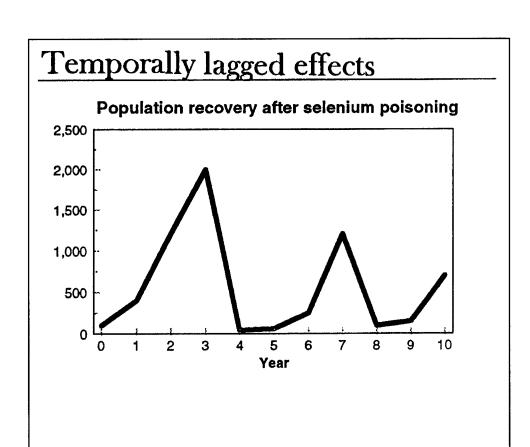
For *sea turtles*, a 10% reduction in juvenile survival *might* well lead to extinction.
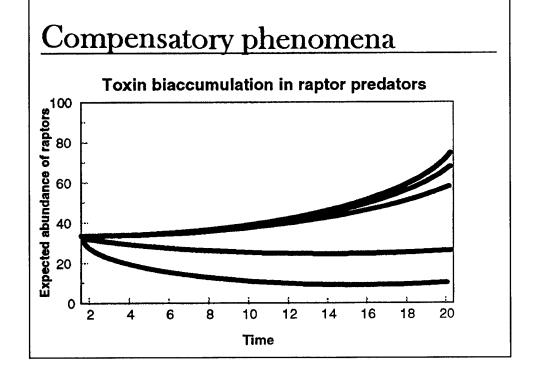
For *striped bass*, a 10% reduction in juvenile survival would *not* yield a detectable impact on the population.

Conflicting effects

Suppose both
    10% decline in survivorship
    10% increase in reproduction
are observed.   Is the overall effect on the population positive or negative?
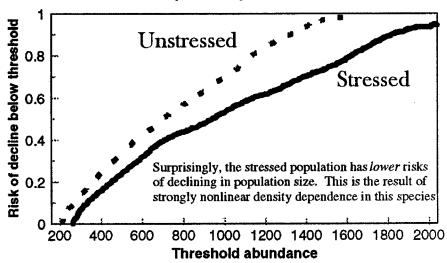
Temporally lagged effects

Population recovery after selenium poisoning

Compensatory phenomena

Toxin biaccumulation in raptor predators

Countintuitive results

Toxicant impact on juvenile fish survival

Unstressed

Stressed

Surprisingly, the stressed population has *lower* risks of declining in population size. This is the result of strongly nonlinear density dependence in this species

Indirect ecological effects

Aquatic mammal

Fish

Plankton

- **Reverberations in abundance**
  (e.g., decline in mammals precipitates increase of fish and decline in plankton)

- **Toxicant biomagnification**
  (e.g., lipid-soluble toxicants become more concentrated up the food chain)

Talking past each other

Toxicant kinetics models

- assume population processes are slow
- neglect changes in populations
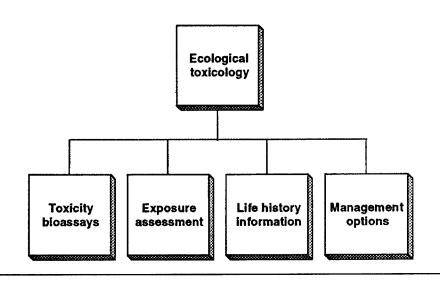
toxicant kinetics

population dynamics

Ecological models

- neglect changes in the concentration
- assume toxicant has equilibrated

A multidisciplinary problem

Ecological toxicology

Toxicity bioassays | Exposure assessment | Life history information | Management options
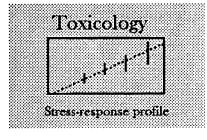
The RAMAS approach
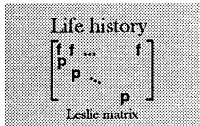
* **Offers wide choice to users**
  Supports modeling choices listed below

* **Checks that the model makes sense**
  Does quality assurance for units, precision & assumptions

* **Translates variability into risk**
  Uses Monte Carlo methods to make the translation

* **Accounts for uncertainty**
  Propagates plus-minus intervals around parameters

* **Uses the language of risk for output**
  Expresses results in terms of risk of population decline, etc.
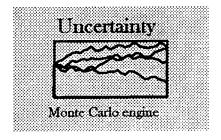
Credibility
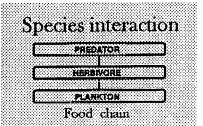
* **Over 700 institutional users worldwide**

* **Used in both research and academia**

* **Named "Distinguished Software"**

* **Favorably reviewed**
  - *Quarterly Review of Biology*
  - *Bulletin of the Ecological Society of America*
  - *Natural Resource Modeling*
  - *Conservation Biology*
  - *Ecological Modelling*

* **Numerous published applications**

RAMAS Ecotoxicology

Toxicology — Stress-response profile

Uncertainty — Monte Carlo engine

Life history — Leslie matrix

Species interaction — Food chain
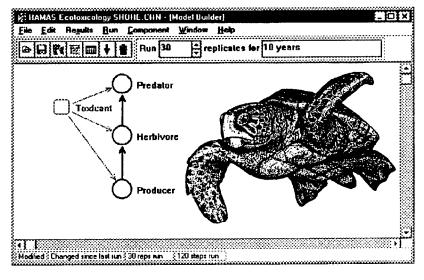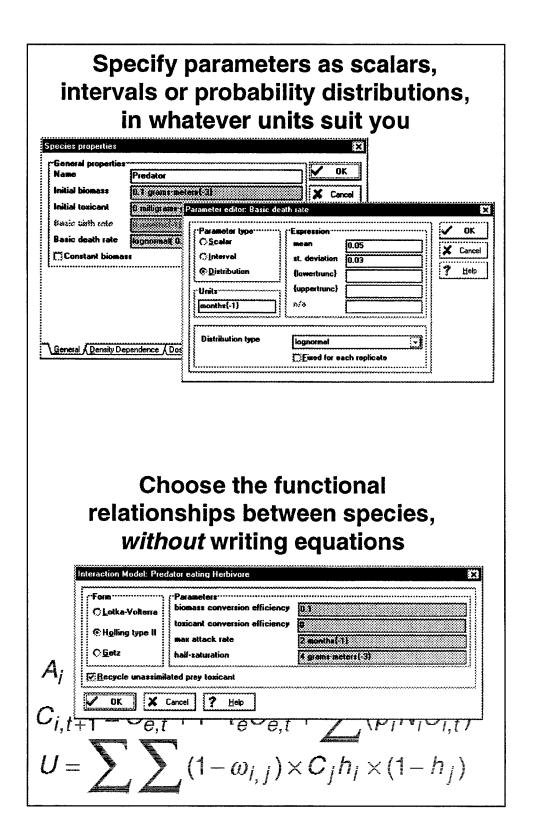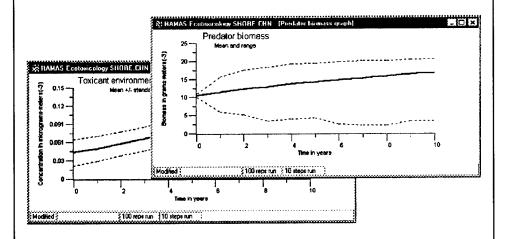
Create a model of population dynamics and toxicant kinetics using a simple Windows interface

Specify parameters as scalars, intervals or probability distributions, in whatever units suit you

Species properties ☒

General properties
Name | Predator
Initial biomass | 0.1 grams meters(-3)
Initial toxicant | 0 milligrams
Basic birth rate |
Basic death rate | lognormal(0.
☐ Constant biomass

✓ OK
✗ Cancel

Parameter editor: Basic death rate ☒

Parameter type
○ Scalar
○ Interval
◉ Distribution

Units
months(-1)

Expression
mean | 0.05
st. deviation | 0.03
(lowertrunc) |
(uppertrunc) |
n/a |

Distribution type | lognormal
☐ Fixed for each replicate

✓ OK
✗ Cancel
? Help

\General / Density Dependence / Dos

Choose the functional relationships between species, *without* writing equations

Interaction Model: Predator eating Herbivore ☒

Form
○ Lotka-Volterra
◉ Holling type II
○ Getz

Parameters
biomass conversion efficiency | 0.1
toxicant conversion efficiency | 0
max attack rate | 2 months(-1)
half-saturation | 4 grams meters(-3)

☑ Recycle unassimilated prey toxicant

✓ OK   ✗ Cancel   ? Help

A_i

$$C_{i,t+1} = C_{e,t} + \dots C_{e,t} + \sum (p_i N_i C_{i,t})$$

$$U = \sum \sum (1 - \omega_{i,j}) \times C_j h_i \times (1 - h_j)$$

Do Monte Carlo simulations to take account of environmental variability and uncertainty in parameter values
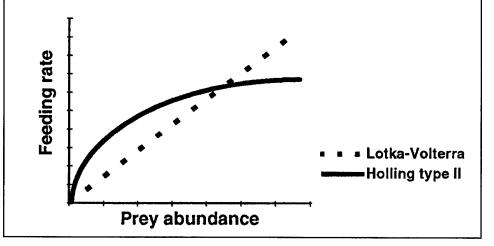
Calculate risks of events such as extinctions or population declines

A simple model of bioaccumulation

Uptake from environment

| Environment | → Toxicant in organism |

Uptake from food

| Feeding |

Dilution by growth
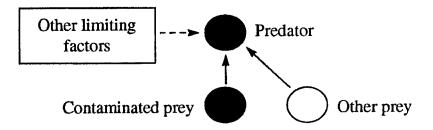
Prey abundance affects feeding rate

- ■ ■ ■ Lotka-Volterra
- —— Holling type II

Feeding rate

Prey abundance
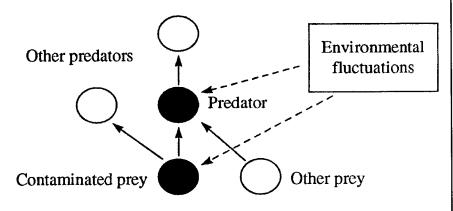
Feeding rate affects growth rate

- •More food can support faster predator growth
- •Alternative prey and other limiting factors can complicate
- •Feeding on contaminated prey increases toxicant uptake

How do prey and predator interact?

Prey and predator won't be independent, but their relationship is complicated by their food web and the variable environment.

Conclusions

•Prey density affects toxicant uptake and predator growth rate.

•Density of predators and prey are unlikely to be independent.

•Predator-prey interactions therefore affect bioaccumulation.

•Modeling ecological interactions makes a big difference for predictions about toxicant concentrations.

Appendix G
You Don't Need to Know a Lot
of Ecology to Make a
Comprehensive Ecological
Risk Assessment

This appendix contains the presentation documents for "You Don't Need to Know a Lot of Ecology to Make a Comprehensive Ecological Risk Assessment" by Scott Ferson - Applied Biomathematics.

You don't need a lot of data for a comprehensive risk analysis

S. Ferson
Applied Biomathematics
scott@ramas.com
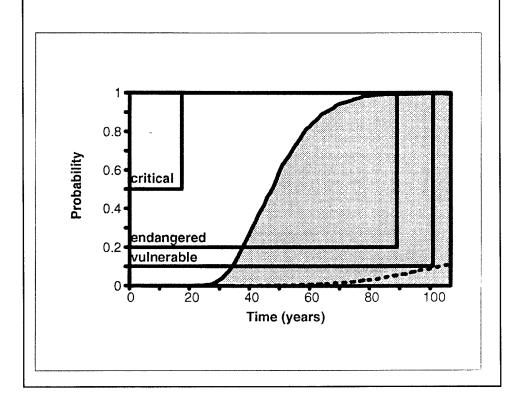
Why risk analysis isn't trusted

- Tool for obstructionists
  - to delay the project
  - to delay remediation
- Helps the other side
  - exposing subtle effects
  - an escape from a finding of toxicity
- ✓ Needs too much data
- ✓ Too expensive (requires consultants)
- ✓ Too complicated

Uncertainty analysis

Good uncertainty analysis can fix the last three problems.

Even though uncertainty is often large, and usually grows pretty fast, it may still permit clear decisions.

Basic considerations

- Underestimating uncertainty is lying

- Overestimating uncertainty is cowardice

- Giving priority to the public good is an ethical obligation

Three major problems
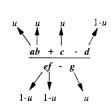
- Correlation and dependency ignored

- Input distributions unknown

- Mathematical structure questionable
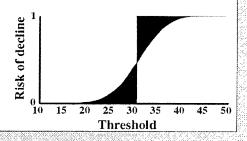
Correlations and dependencies
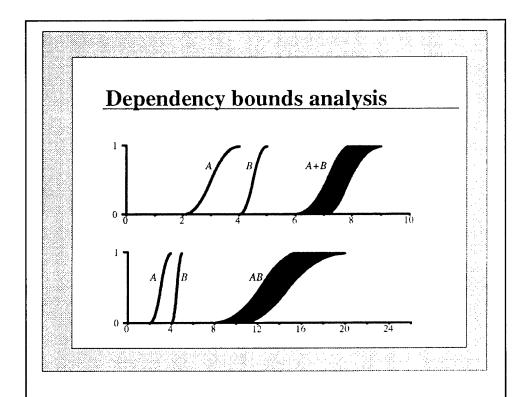
0) Independence assumptions

1) Dispersive Monte Carlo sampling

2) Dependency bounds analysis

Dispersive Monte Carlo sampling

- Assume extreme correlations so result is as broad as possible
- Computationally cheaper than ordinary Monte Carlo methods

Dependency bounds analysis
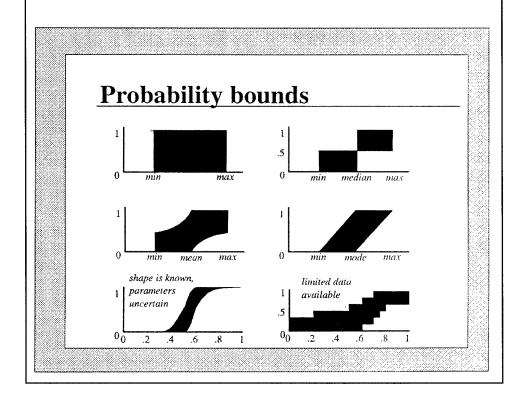
Input distributions unknown

0) Default distributions

1) Maximum entropy

2) Probability bounds

Maximum entropy

- **Generalizes Laplace's Principle of Insufficient Reason**
  - {min, max} ↦ **uniform**
  - {mean, variance} ↦ **normal**
  - {min, max, mean} ↦ **beta**
  - {min = 0, mean} ↦ **exponential**
- **Yields distribution with minimum bias and maximum uncertainty under the constraints**

Probability bounds
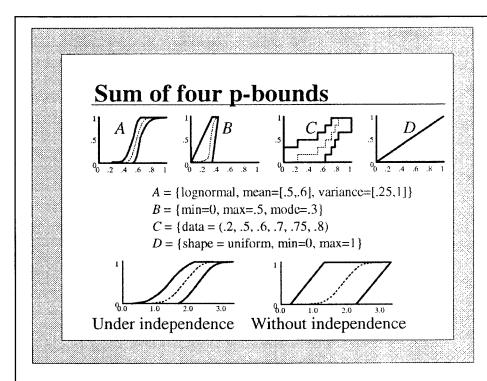
Probability bounds

{min, max}
{min, max, mean}
{min, max, median}
{min, max, mean=median}
{min, max, mode}
{min, max, median=mean}
{mean, variance}
{shape=symmetric, mean, variance}
{shape=canonical, parameters}

P-bounds arithmetic

- +, −, ×, ÷, ^, min, max, exp, log, etc.
- **Quicker than Monte Carlo**
- **Guaranteed to bound answer**
- **Optimal solutions in most cases**

Sum of four p-bounds

A = {lognormal, mean=[.5,.6], variance=[.25,1]}
B = {min=0, max=.5, mode=.3}
C = {data = (.2, .5, .6, .7, .75, .8)
D = {shape = uniform, min=0, max=1}

Under independence   Without independence

Mathematical structure

*Given that validation is usually impossible
when data are scarce...*

0) "My model is correct"

1) Comprehensive battery of checks

**2) Incorporate model uncertainty into
the analysis**

Battery of checks

- **Generic checks**
  - Dimensional and unit concordance
  - Feasibility of correlation structure
  - Consistence of independence assumptions
  - Single instantiations of repeated variables
- **Checks against domain knowledge**
  For instance, in ecological risk analysis...
  - Population sizes nonnegative
  - Trophic relations influence bioaccumulation
  - Food web structure constrained

P-bounds handles model uncertainty
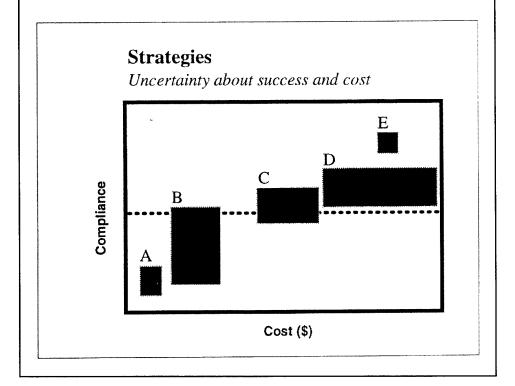
- **Reducible to parameter choice**
- **Reducible to distribution choice**

Advantages of p-bounds

- **Much faster than second-order Monte Carlo**
- **Easy (graphical) parameterization**
- **Handles uncertainty about**
  - parameter values
  - distribution shapes
  - dependence and correlation among variables
  - even the form of the model itself
- **Faithful to frequentist interpretation**

Strategies
Uncertainty about success and cost

Appendix H
Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model

This appendix contains the presentation documents for "Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model" by Bill Mills - Tetra Tech, Inc.

Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model

Prepared For:
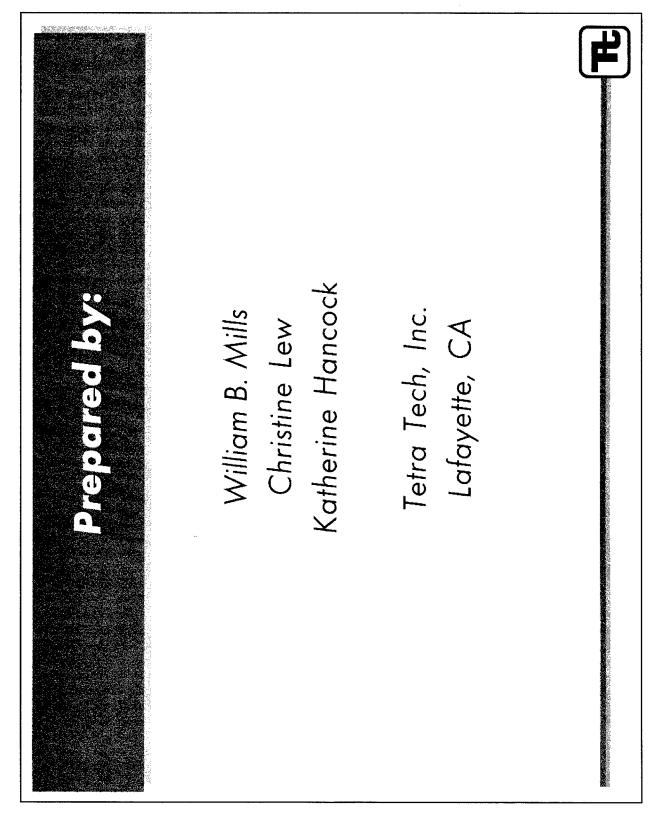
U.S. Army Engineer Waterways Experiment Station Risk Assessment Modeling Workshop
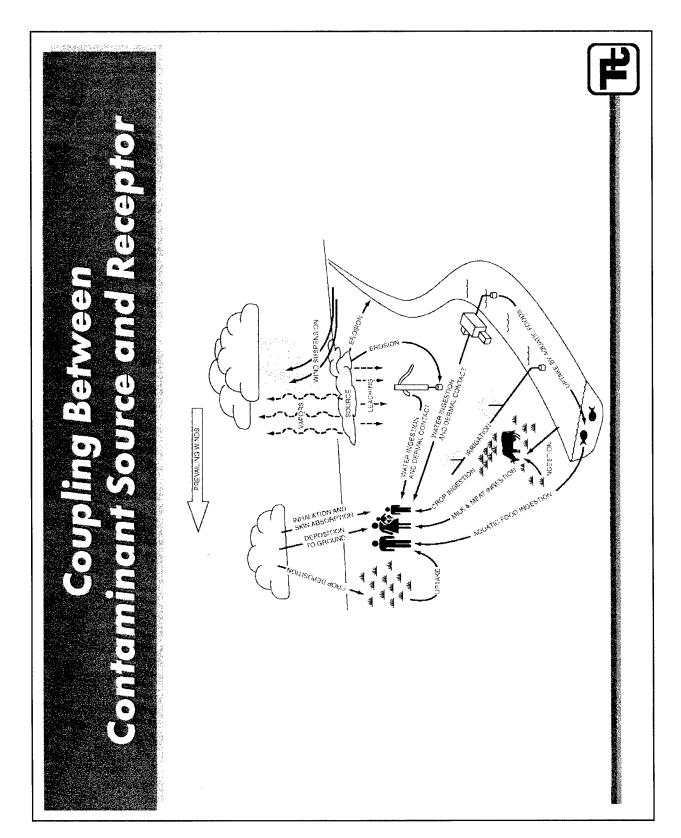
New Orleans, Louisiana

May 14-15 1998

Prepared by:

William B. Mills

Christine Lew

Katherine Hancock

Tetra Tech, Inc.

Lafayette, CA

Purpose of Presentation

❑ Provide an Introduction to MMSOILS: Its uses and limitations
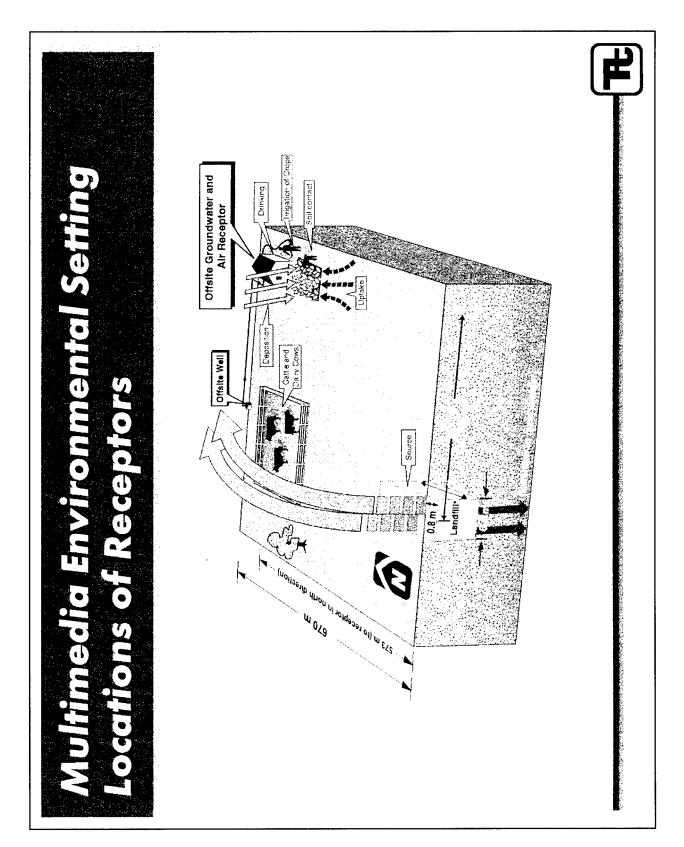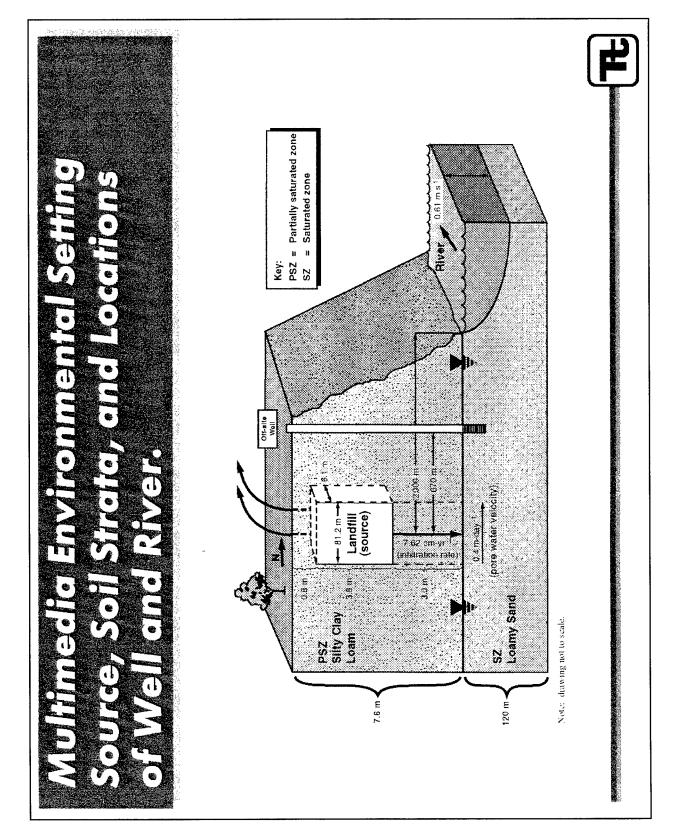
❑ Demonstrate how MMSOILS used in one EPA Program (HWIR) to provide an initial assessment of many sites

Appendix H   Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model

Coupling Between Contaminant Source and Receptor

Multimedia Environmental Setting
Locations of Receptors

Multimedia Environmental Setting Source, Soil Strata, and Locations of Well and River.

Key:
PSZ = Partially saturated zone
SZ = Saturated zone

Landfill (source)

81.2 m

Off-site Well

7.62 cm/yr (infiltration rate)

0.4 m-day⁻¹ (pore water velocity)

River 0.61 m·s⁻¹

PSZ Silty Clay Loam

SZ Loamy Sand

7.6 m

120 m

Note: drawing not to scale.

Selected Features of MMSOILS Multimedia Models

❏ Contaminant Transformation and Fate Processes

❏ Intermedia Contaminant Fluxes

❏ Exposure Pathways

❏ Human Health Risk Measures

❏ Media-specific Transport

Appendix H   Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model

Application to EPA's HWIR

☐ HWIR:

    ◆ Hazardous Waste Identification Rule

☐ Purpose of HWIR:

    ◆ To evaluate if certain low-risk wastes can be disposed of as *nonhazardous*

☐ "Exit" Rule:

    ◆ At what concentrations can specific chemicals "exit" hazardous waste disposal requirements <u>and</u> be protective of human health and the environment?

Scope of HWIR

☐ Nationwide:
- ◆ Disposal could occur at WMUs throughout the United States

☐ Chemicals:
- ◆ Approximately 400 Chemicals

☐ WMUs:
- ◆ Landfills
- ◆ Impoundments
- ◆ Waste piles

EPA's Approach

☐ Multimedia/Multi-pathway

☐ Risk Based:
  ◆ Human health and Ecological

☐ Site Based
  • Create plausible sites (hundreds per source type) throughout US
  • Assume each chemical could be disposed at each site

Factors that Influence Computational Effort to Implement HWIR

◻ Hundreds of sites

◻ 5-6 source types

◻ 400+ chemicals

◻ Range of source concentrations

◻ Monte Carlo loops (2)

Appendix H   Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model

Computational Burden for One
Alternative HWIR Assessment Strategy

T_{MMR} = 5 sec

T_{MMR} = 1 sec

- 2 m/c Loops
- 200 sites
- 5 sources
- 10 Alternative source concentration?

Number of chemicals

Time, centuries

Computational Burden for Simpler HWIR Assessment Strategy

T_{MMR} = 5 sec

T_{MMR} = 1 sec

- 200 sites
- 5 sources
- 10 source concentrations

Number of chemicals

Time, hours

100   10   1   0.1

0   5   10   15   20   25   30   35   40

Appendix H   Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model

Investigation of Other Means of Reducing Computational Burdens

☐ Making use of linearity

☐ Grouping of chemicals

☐ Risky Vs nonrisky sites

☐ Minimizing number of random variables

How to Control Computational Burden

☐ Examine linearity in source concentration (HWIR exit concentration)

Appendix H   Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model

Percent of Receptors Protected versus Different Risk Levels for Various Cw's

Results of Step-wise Multiple Linear Regression Analysis Using Ranked Parameters for Benzene Drinking Water Risk (790 Sites)

$R^2 = 0.5985$

1 Groundwater Receptor Y-Distance
2 Source Width
3 Aquifer Depth
4 Annual Recharge

Number of Variables

R-squared

CDF of Benzene Drinking Water Risk for 8, 12, and All Random Variables

Appendix H   Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model

Range of Groundwater Dilution - Attention Factor for Selected Chemicals, all sites

Atmospheric Dilution-Attenuation Factor

Drinking Water Risk

Chemical Properties of HWIR Chemicals Grouped by Drinking Water Hazard Index

Matrix of Drinking Water Risk by Chemical and Site

Chemical

Site

Key:

- □ R < 10⁻⁶ → $R < 10^{-6}$
- ▫ $10^{-6} \le R \le 10^{-4}$
- ▨ $R > 10^{-4}$
- NA Chemical does not have carcinogenic risk

Conclusion

☐ Screening-level multimedia/multipath model applied preliminarily to HWIR program

☐ Purpose is to help streamline the expected large computational effort

☐ Means to accomplish this are being investigated: linearity; site grouping; chemical grouping

Appendix I
Metapopulation Models and Ecological Risk Analysis: A Habitat-Based Approach to Biodiversity

This appendix contains the presentation documents for "Metapopulation Models and Ecological Risk Analysis: A Habit-Based Approach to Biodiversity" by H. Resit Akcakaya - Applied Biomathematics. Complete information for references cited in this appendix was provided in handouts at the time of the workshop.

METAPOPULATION MODELS AND ECOLOGICAL RISK ANALYSIS: A HABITAT-BASED APPROACH TO BIODIVERSITY CONSERVATION

H. Reşit Akçakaya

Applied Biomathematics
100 North Country Road
Setauket, New York 11733

Risk Assessment Modeling Workshop
New Orleans, 14-15 May 1998

resit@ramas.com

Importance of metapopulation dynamics

Modelers ingore spatial structure at their own risk

Spatially explicit metapopulation models

Practical compromise between complexity and applicability
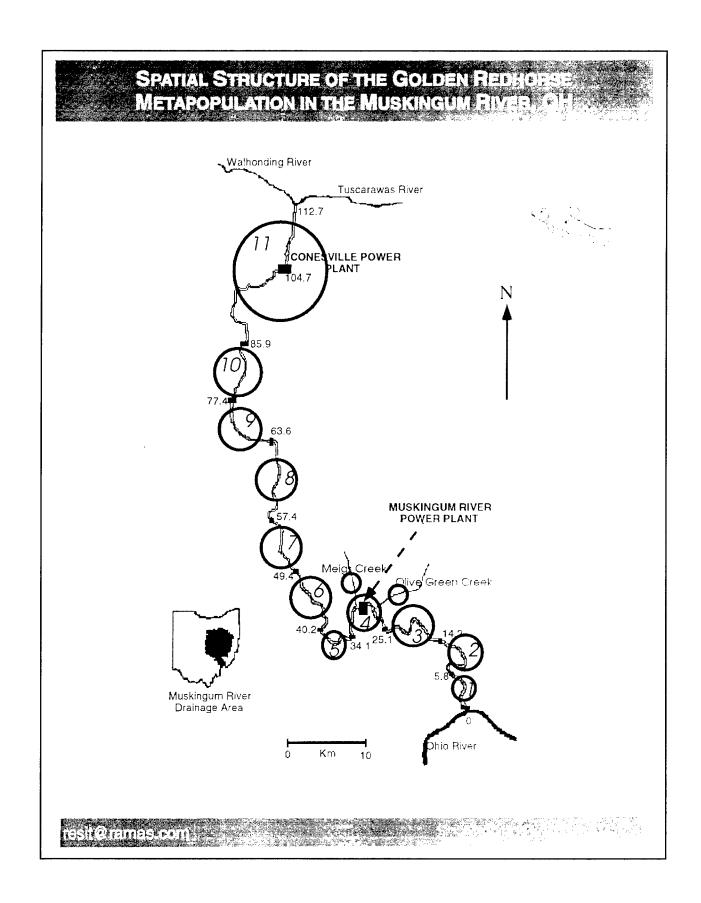
Future directions

Incorporating habitat relationships

Multi-species approaches

Metapopulations in trophic chains

SPATIAL STRUCTURE OF THE GOLDEN REDHORSE METAPOPULATION IN THE MUSKINGUM RIVER, OH

Walhonding River

Tuscarawas River

112.7

11

CONESVILLE POWER PLANT
104.7

N

85.9

10

77.4

9

63.6

8

57.4

MUSKINGUM RIVER
POWER PLANT

7

49.4

Meigs Creek

Olive Green Creek

6

40.2

5

34.1

4

25.1

3

14.2

2

5.8

1

0

Muskingum River
Drainage Area

0   Km   10

Ohio River

resit@ramas.com

Appendix I   Metapopulation Models and Ecological Risk Analysis: A Habitat-Based Approach to Biodiversity

WHY ARE METAPOPULATIONS IMPORTANT?

Assessing impacts at the metapopulation level

- Impacts on single populations
- Fragmentation:

    change in distribution of habitat patches

    decrease in total area

    smaller populations

    increased edge effects

- Decreased dispersal / Increased isolation

Evaluating management options at the metapopulation level

- Reintroduction/translocation
- Reserve design
- Habitat corridors

Complicated dynamics

- Many models of single populations don't make a metapopulation model
- Extinction risk is sensitive to additional factors at the metapopulation level

resit@ramas.com   APPLIED BIOMATHEMATICS

WHAT MAKES METAPOPULATION DYNAMICS DIFFERENT?

Factors affecting population dynamics

- Demography: survival, fecundity, growth
- Age or stage structure
- Density dependence
- Environmental fluctuations, catastrophes
- Demographic stochasticity

Additional factors affecting metapopulation dynamics

- Number of populations
- Geographic configuration
- Spatial correlation
- Migration patterns

resit@ramas.com

Model	Advantages	Disadvantages
Occupancy	Analytical solution Generalizations	Unrealistic assumptions Difficult parameters Few or infinitely many patches
Spatially explicit	Flexible and realistic Few implicit assumptions	Numerical errors possible Data intensive Difficult to add genetics
Individual-based	Very flexible and realistic	Easy to make numerical and/or logical errors Very data-intensive Sensitive to behavioral assumptions

reslt@ramas.com   APPLIED BIOMATHEMATICS

Incorporating habitat into metapopulation models

1. Identifying species-habitat relationship
2. Determining habitat patches based on distribution of suitable habitat
3. Estimating population-level and metapopulation-level parameters based on habitat-related variables:

Metapopulation model parameters:	Based on habitat variables:
initial population abundance, $N_i(0)$	total habitat suitability
carrying capacity of the patch, K_i	average habitat suitability
stage-specific survival, S_k	edge length (perimeter)
stage-specific fecundity, F_k	patch area (or core area)
population growth rate, R_{max}	habitat variables (vegetation, elevation, flow, temperature)
dispersal among patches, M_{ij}	
correlation among patches, ρ_{ij}	inter-patch distances
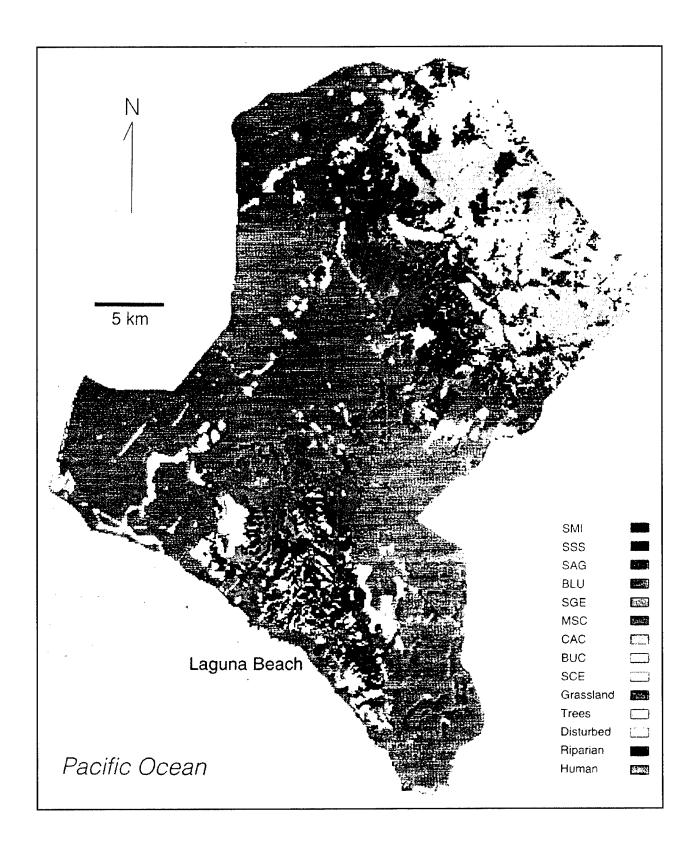
A Habitat-based Metapopulation Model of the California Gnatcatcher in Orange County, CA
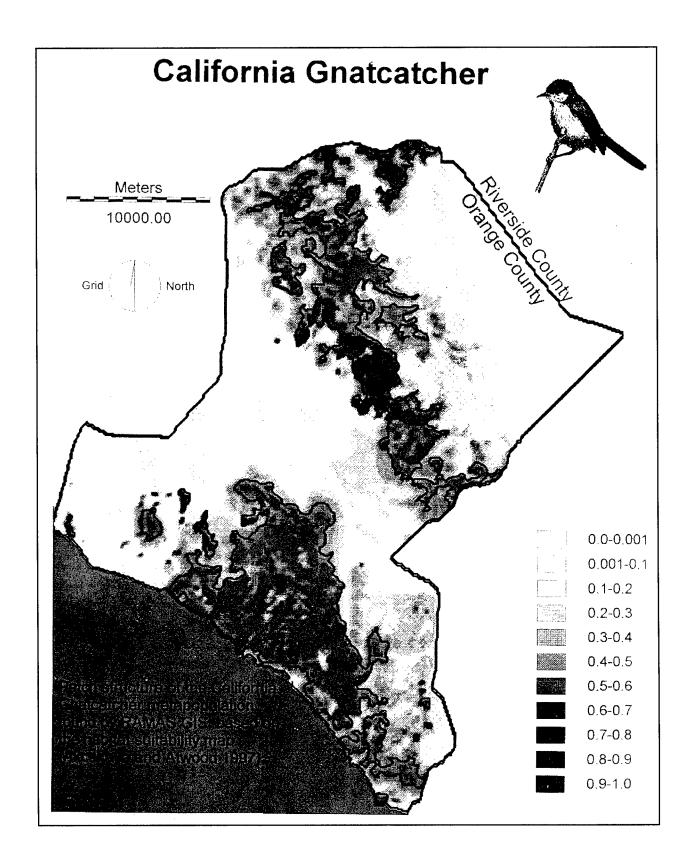
H. Reşit Akçakaya
Applied Biomathematics, Setauket, NY
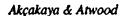
Jonathan Atwood
Manomet Observatory, Manomet, MA

Appendix I   Metapopulation Models and Ecological Risk Analysis: A Habitat-Based Approach to Biodiversity

California Gnatcatcher

Meters

10000.00

Grid   North

Riverside County
Orange County

Patch structure of the California
Gnatcatcher metapopulation
obtained by RAMAS GIS based on
the habitat suitability map of
Ogden and Atwood 1997.

	0.0-0.001
	0.001-0.1
	0.1-0.2
	0.2-0.3
	0.3-0.4
	0.4-0.5
	0.5-0.6
	0.6-0.7
	0.7-0.8
	0.8-0.9
	0.9-1.0
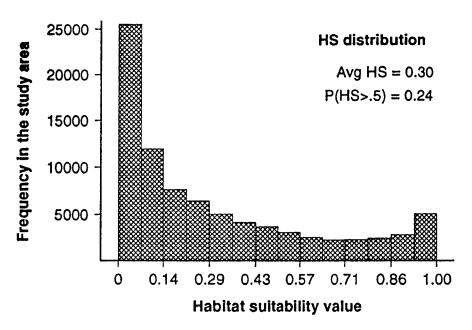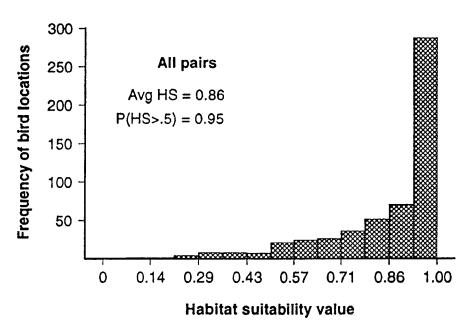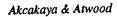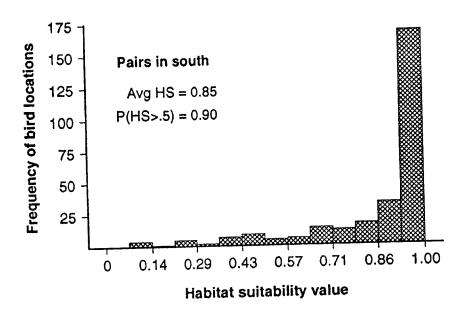
Habitat suitability (HS) values for California Gnatcatchers in the study area, calculated for each of 85,333 1-ha cells.
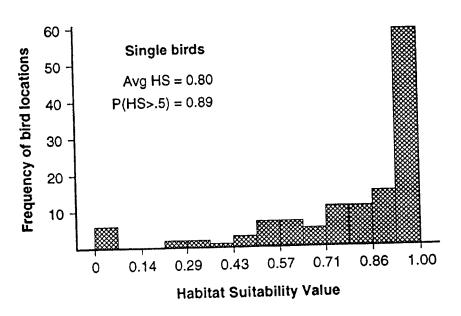
Goodness of fit: Habitat suitability (HS) values of locations where California Gnatcatcher pairs were observed in the study area.

Appendix I   Metapopulation Models and Ecological Risk Analysis: A Habitat-Based Approach to Biodiversity

Pairs in south

Avg HS = 0.85

P(HS>.5) = 0.90

Frequency of bird locations

Habitat suitability value

Validation 1 (North - to - South):
Habitat suitability (HS) values of locations of pairs in the south.
Predicted with the HS function using the locations of pairs in the north.

Single birds

Avg HS = 0.80

P(HS>.5) = 0.89

Frequency of bird locations

Habitat Suitability Value

Validation 2 (Pair - to - Single):
Habitat suitability (HS) values of locations of single birds.
Predicted with the HS function using the locations of pairs.

California Gnatcatcher
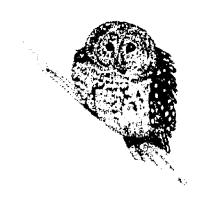
	Juvenile	Adult
Juvenile	0.5376*	0.8899
Adult	0.3441	0.4975

*post-reproductive census: juvenile fecundity $= P_{JB} \cdot M$
= proportion of last year's juveniles that are breeders this year, multiplied with number of fledglings per breeder.

Spotted Owl
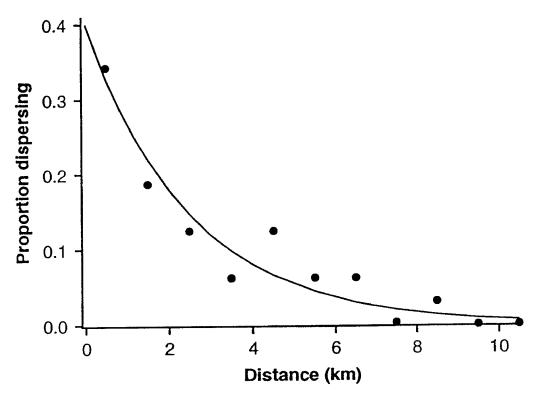
	Juvenile	Subadult	Adult
Juvenile	0.0258	0.0779	0.1288
Subadult	0.884	0	0
Adult	0	0.884	0.884
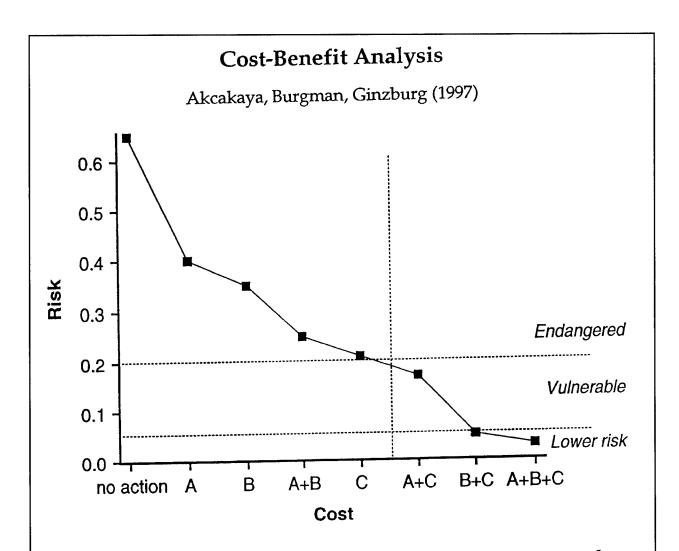
*pre-reproductive census: fecundity $= M \cdot S_0$
= number of fledglings per breeder, multiplied with the survival rate from fledgling to (1-year-old) juvenile

Metapopulation dynamics: Dispersal (migration)

- Biology of the species
- Landscape characteristics
- Distance among patches
- Direction (e.g., downstream vs. upstream)
- Age or stage (e.g., only juveniles disperse)
- Density (e.g., higher emigration when crowded)
- Variability (demographic stochasticity)
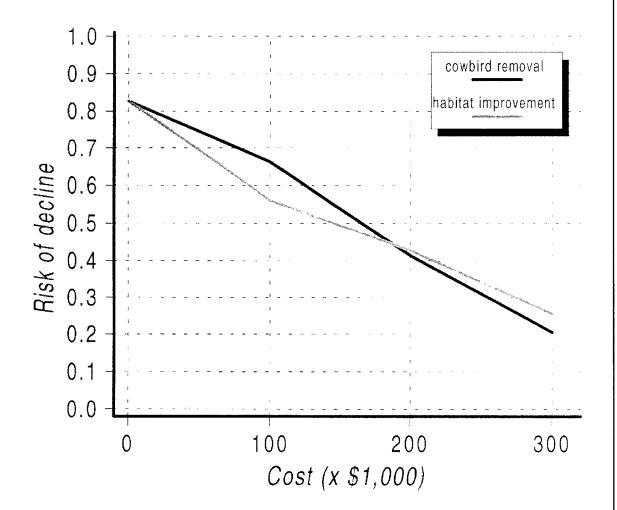
Proportion of dispersing juveniles as a function of distance (in km). Data from Atwood et al. (1995b). The curve is the function $y=0.4 \cdot \exp(-x/2.5)$.

Cost-Benefit Analysis

Akcakaya, Burgman, Ginzburg (1997)

Risk of extinction of a hypothetical metapopulation with no management ("no action" option), and under 7 options (which involve improving the habitat in one, two or all three of the three habitat patches, A, B,and C).
The options are in order of increasing cost from left to right.
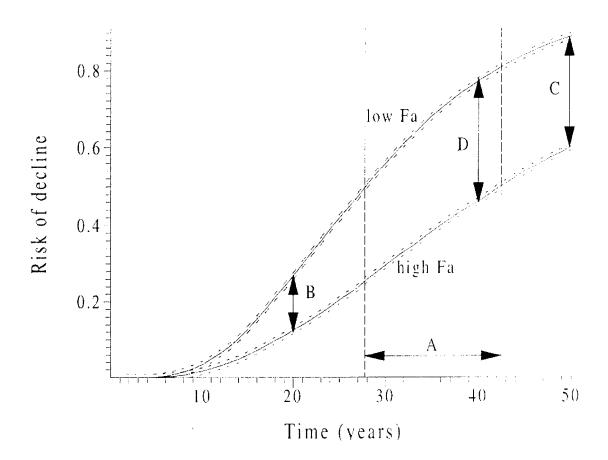
Using the model to evaluate management options: Hypothetical comparison of two management options (removing cowbirds that parasitize gnatcatcher nests and improving habitat) in terms of their cost and the reduction in the risk of decline.
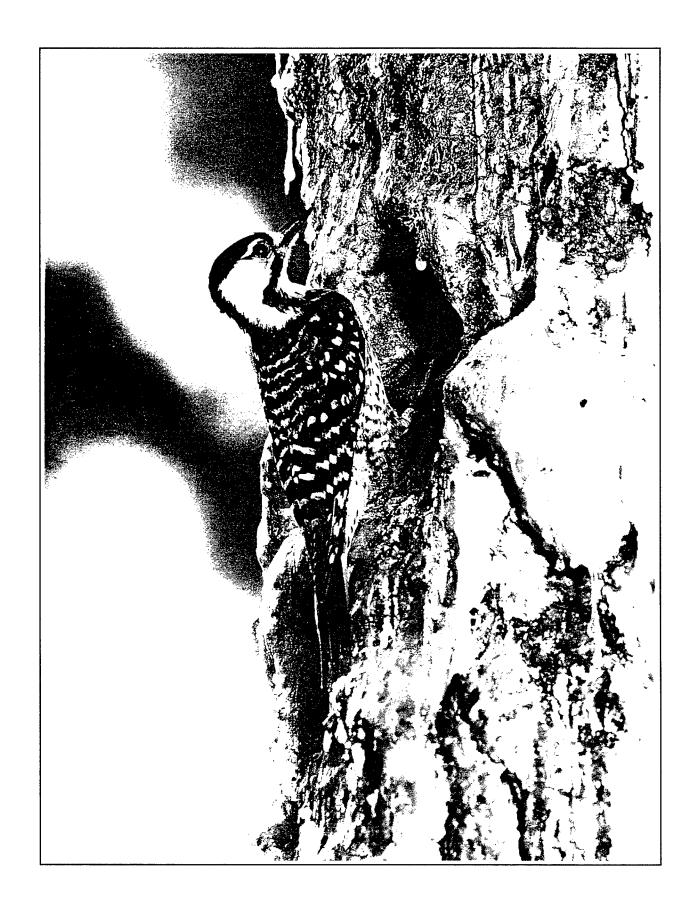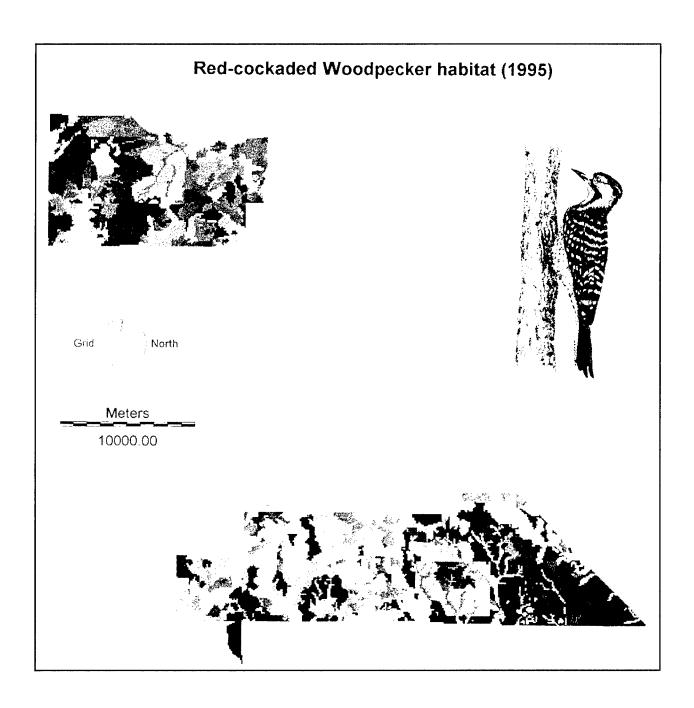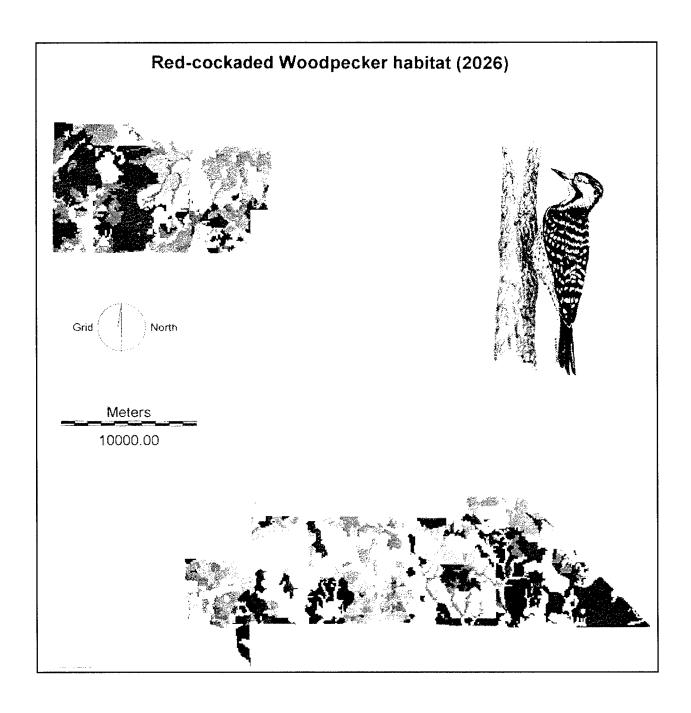
Sensitivity of risk of decline to adult survival (S_a). The curves show the probability of falling below the metapopulation threshold as a function of time. The vertical dashed lines show the median time to decline. The arrows show four sensitivity results: the difference between median time to decline (A), the difference in risk of decline in 20 years (B) and 50 years (C), and the maximum difference in risk of decline (D), which in this case occurred around year 30.

Appendix I   Metapopulation Models and Ecological Risk Analysis: A Habitat-Based Approach to Biodiversity

Red-cockaded Woodpecker habitat (1995)

Grid   North

Meters

10000.00

Appendix I   Metapopulation Models and Ecological Risk Analysis: A Habitat-Based Approach to Biodiversity

Red-cockaded Woodpecker habitat (2026)

Grid / North

Meters

10000.00
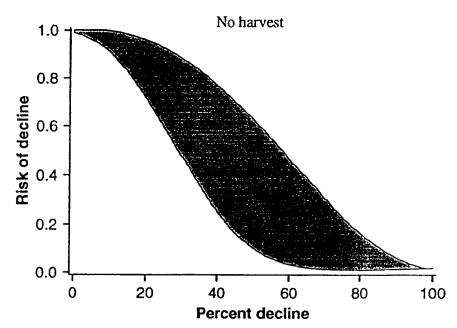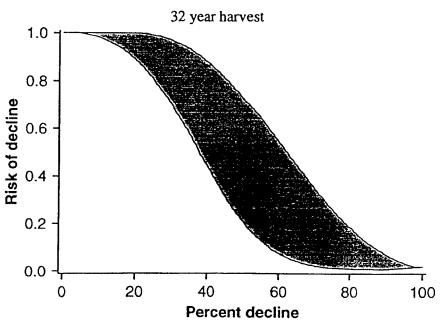
Uncertainty in Risk of Decline of the Red-cockaded Woodpecker Populations at Fort Polk

No harvest
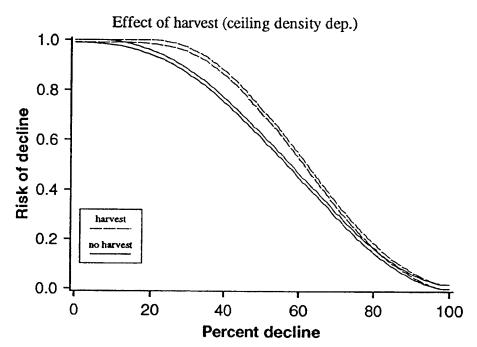
Risk of decline in 60 years with no timber harvest.

32 year harvest
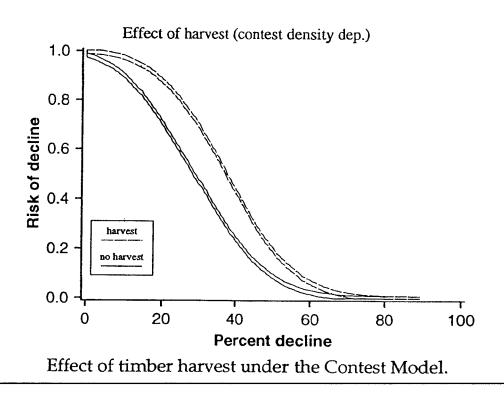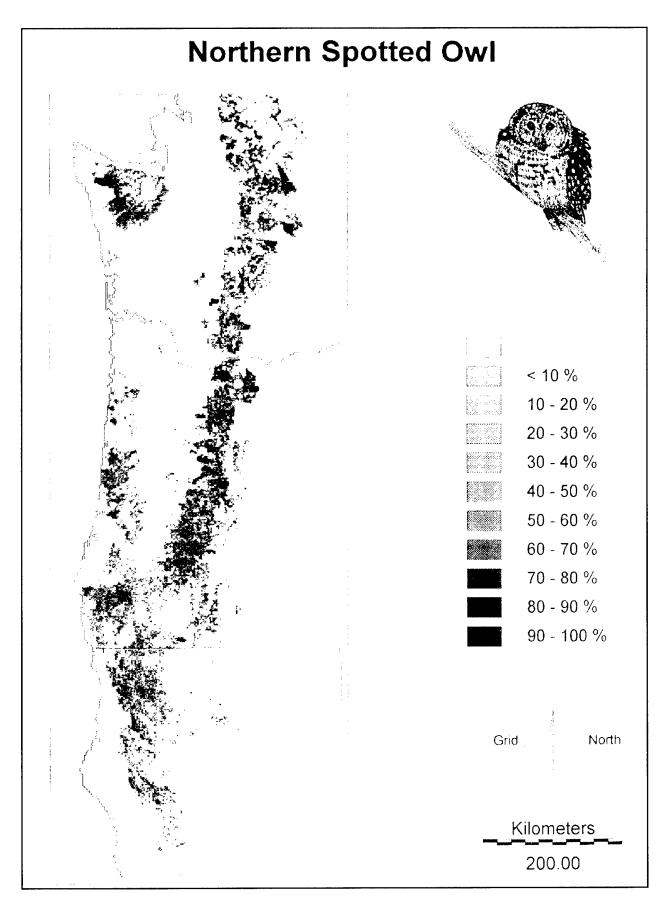
Risk of decline in 60 years with timber harvest from 1995 to 2026.

Appendix I   Metapopulation Models and Ecological Risk Analysis: A Habitat-Based Approach to Biodiversity
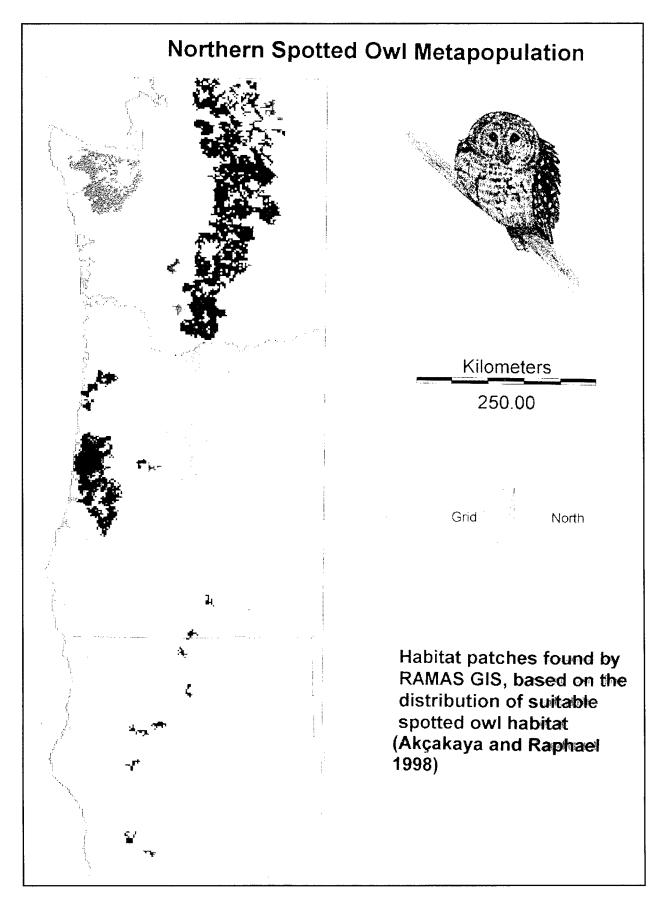
Impact Assessment Despite Uncertainty

Effect of harvest (ceiling density dep.)

Effect of timber harvest under the Ceiling Model.

Effect of harvest (contest density dep.)

Effect of timber harvest under the Contest Model.

Northern Spotted Owl

	< 10 %
	10 - 20 %
	20 - 30 %
	30 - 40 %
	40 - 50 %
	50 - 60 %
	60 - 70 %
	70 - 80 %
	80 - 90 %
	90 - 100 %

Grid   North

Kilometers

200.00

Appendix I Metapopulation Models and Ecological Risk Analysis: A Habitat-Based Approach to Biodiversity

Northern Spotted Owl Metapopulation

Kilometers

250.00

Grid   North

Habitat patches found by
RAMAS GIS, based on the
distribution of suitable
spotted owl habitat
(Akçakaya and Raphael
1998)

Akçakaya, H.R. and M.G. Raphael (1998) Assessing Human Impact Despite Uncertainty: Viability of the Northern Spotted Owl Metapopulation in the Northwestern U.S. *Biodiversity and Conservation* (in press).
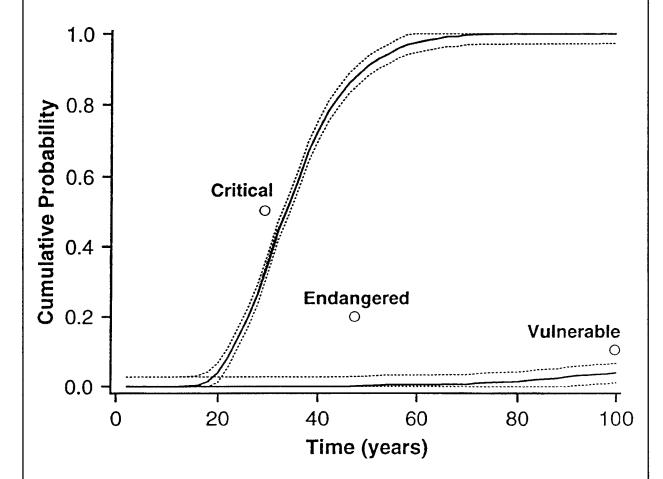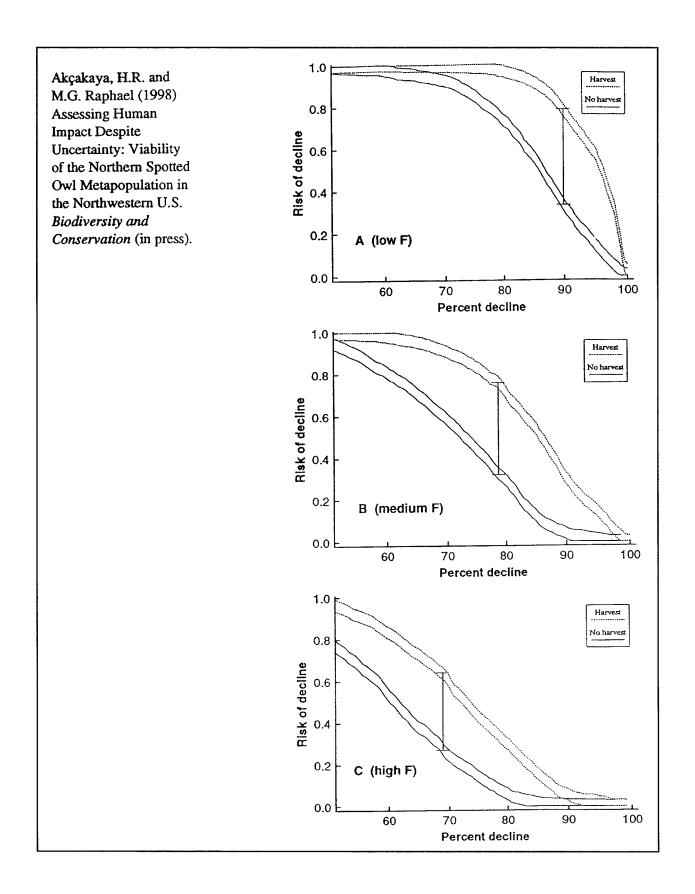
Figure 5. Time to extinction with the mid-range parameters (curves close to the x-axis), and with a pessimistic scenario. The thick curves show the cumulative probability that the metapopulation abundance will fall below the extinction threshold (530 owls) at or before a given year. The dotted curves show 95% confidence interval of the risk curve, and the circles indicate IUCN's risk-based criteria for categories of threat (see text).

Akçakaya, H.R. and
M.G. Raphael (1998)
Assessing Human
Impact Despite
Uncertainty: Viability
of the Northern Spotted
Owl Metapopulation in
the Northwestern U.S.
*Biodiversity and
Conservation* (in press).

Multispecies Assessments

- habitat suitability maps for several species in the same landscape
- composite map with weighted average of all single-species maps
- *Assessment:*
  - "conservation value" of predefined parcels
  - identifying patches or locations with high "multispecies habitat suitability"
- *Issues:*
  - identifying "representative" or "indicator" species
  - determining weights (e.g., based on extinction risk)
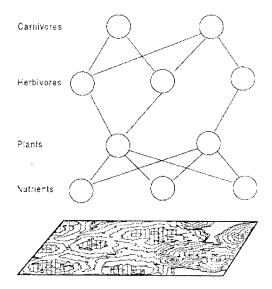
resit@ramas.com

Community-metapopulation Models

- each trophic level represented as a metapopulation
- each metapopulation at a different spatial scale
- connections between metapopulations based on energy flow
- *Issues:*
  - coordinating multiple spatial and temporal scales
  - determining trophic relationships (predation function, etc.)
  - identifying functional groups (trophic level, guild, species)
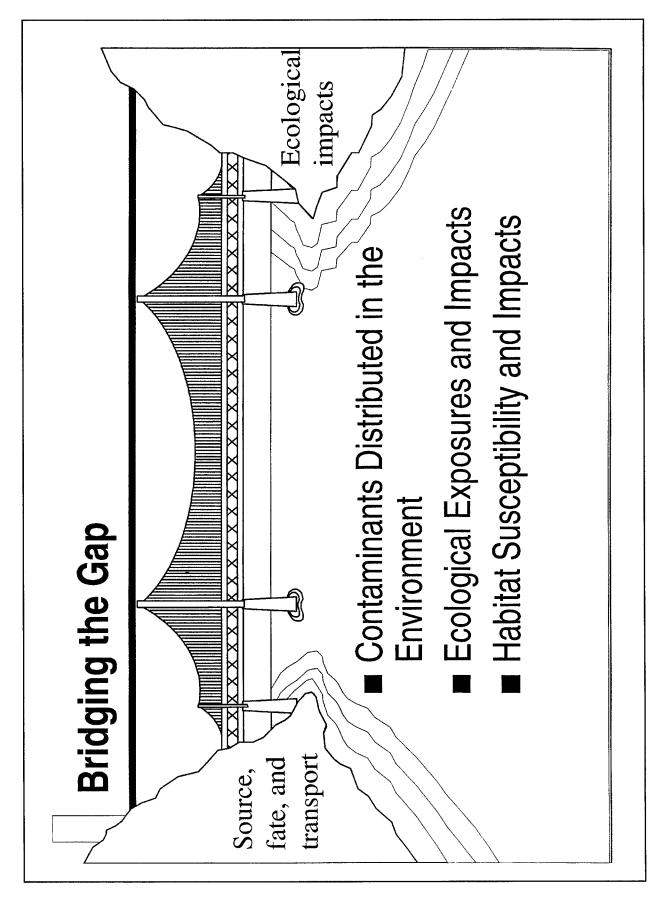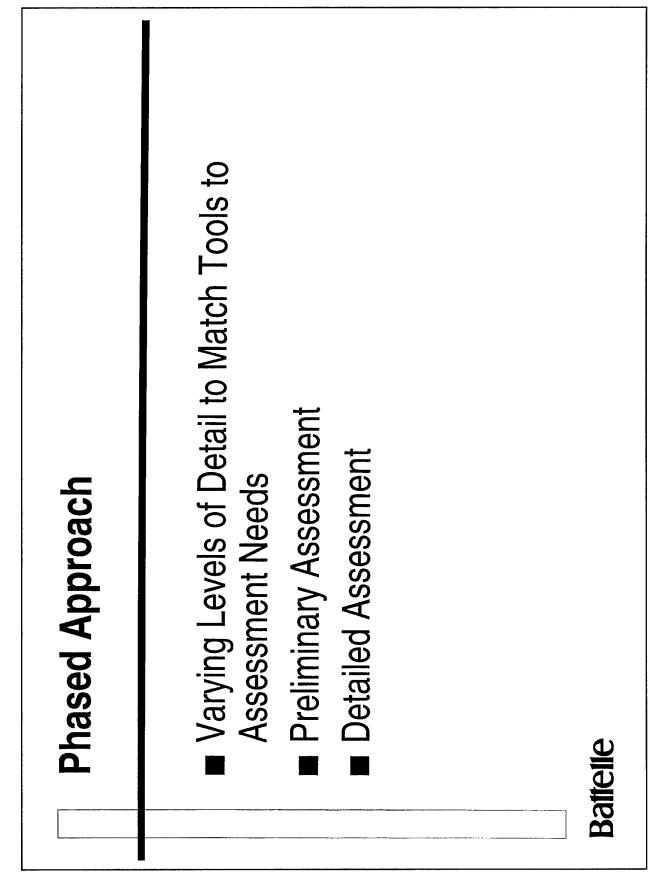
Appendix J
Ecological Risk in an
Integrated Intermedia System

This appendix contains the presentation documents for "Ecological Risk in an Integrated Intermedia System" by Gene Whelan - Battelle Pacific Northwest National Laboratory.

Ecological Risk in an Integrated Intermedia System

G. Whelan, Ph.D.

Pacific Northwest National Laboratory

Richland, WA

Battelle

Bridging the Gap

Source, fate, and transport

Ecological impacts

■ Contaminants Distributed in the Environment

■ Ecological Exposures and Impacts

■ Habitat Susceptibility and Impacts

Phased Approach

- Varying Levels of Detail to Match Tools to Assessment Needs

- Preliminary Assessment

- Detailed Assessment

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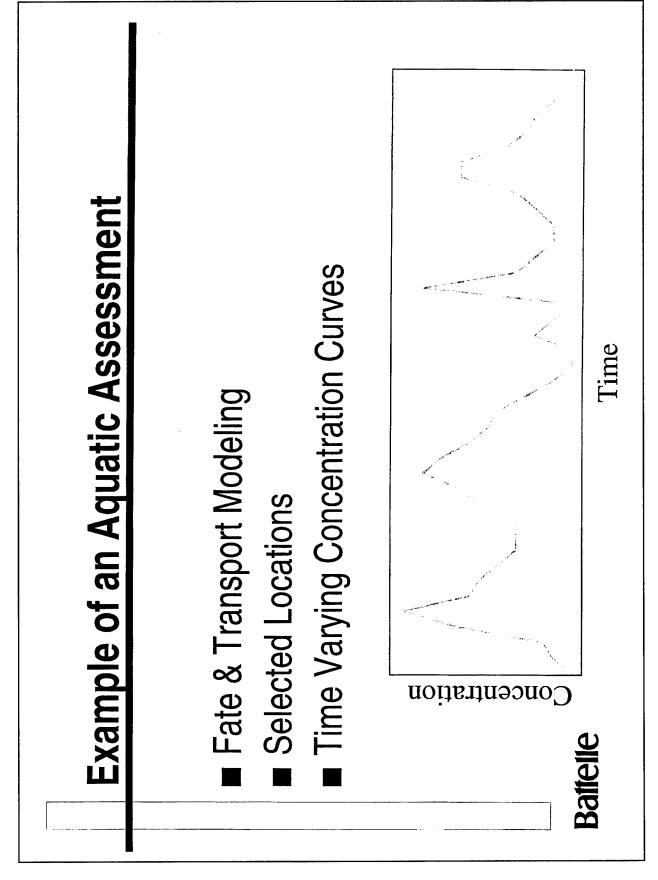
Illustrative Ecological Models
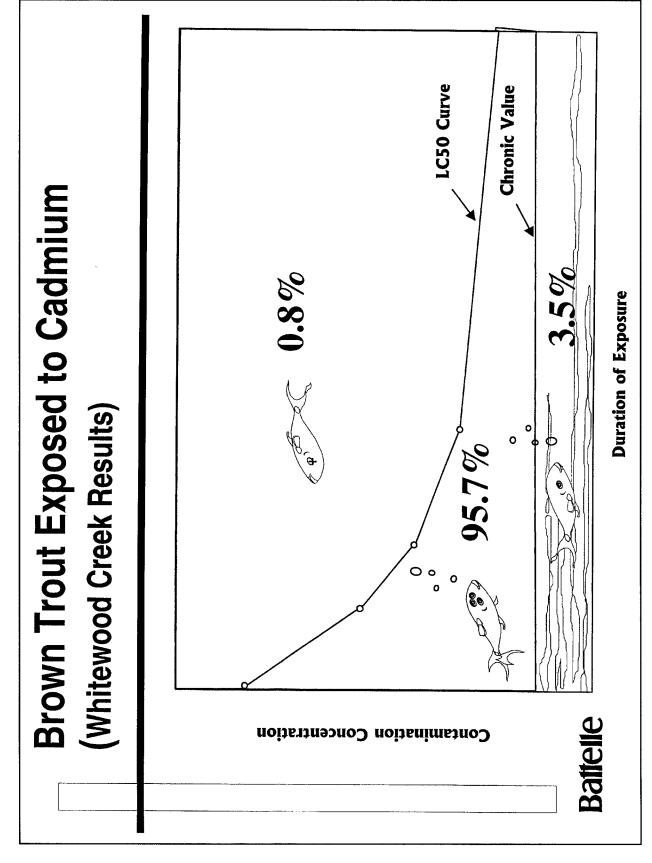
- Wildlife Ecological Assessment Program (WEAP)
- Ecological Contaminant Exposure Model (ECEM)
- Health and Ecological Risk Management and Evaluation System (HERMES)
- Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES)

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"WEAP"

Wildlife Exposure Assessment Program
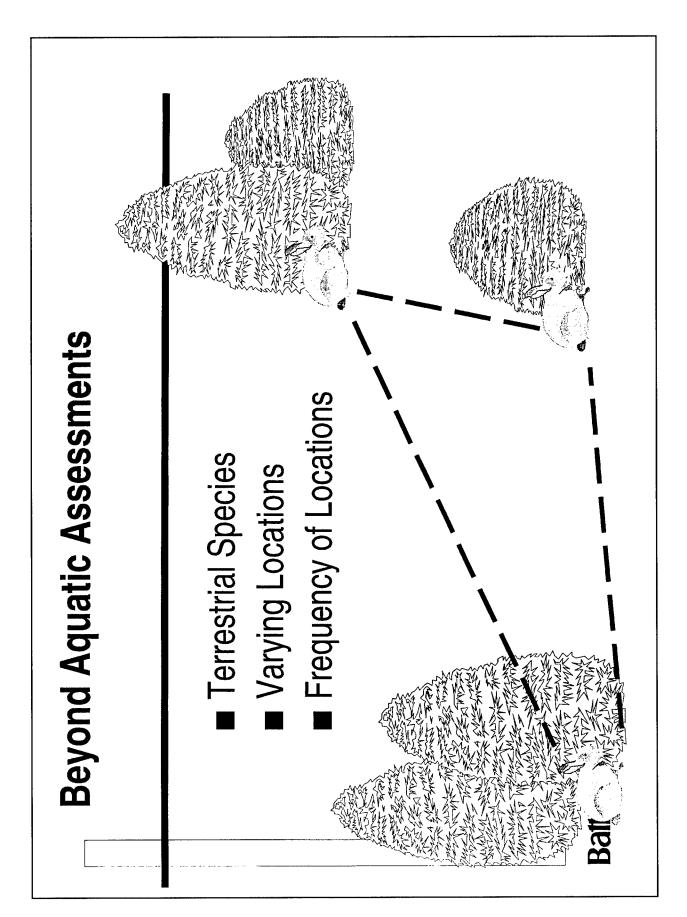
Ecological Exposure Assessment Modeling with Frequency Analysis

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WEAP

- Represents a Preliminary Assessment
- Correlates Exposure and Effect, using Laboratory Data
- Analyzes and Correlates Concentration and Duration of Exposure
- Accounts of Frequency of Occurrence

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Example of an Aquatic Assessment

- Fate & Transport Modeling
- Selected Locations
- Time Varying Concentration Curves

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Brown Trout Exposed to Cadmium
(Whitewood Creek Results)

0.8%

95.7%

3.5%

LC50 Curve

Chronic Value

Contamination Concentration

Duration of Exposure

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Beyond Aquatic Assessments

- Terrestrial Species
- Varying Locations
- Frequency of Locations

"ECEM"

Ecological Contaminant Exposure Model

A Food-Wed Based Ecological Exposure Assessment Tool

Battelle

Developed by
Pacific Northwest National Laboratory
for the U. S. Department of Energy

For information contact:

Charles A. Brandt, Ph.D.

Pacific Northwest National Laboratory

P.O. Box 999 MSIN K6-85

Richland, WA 99352

(509) 376-5345

charles.brandt@pnl.gov

Battelle
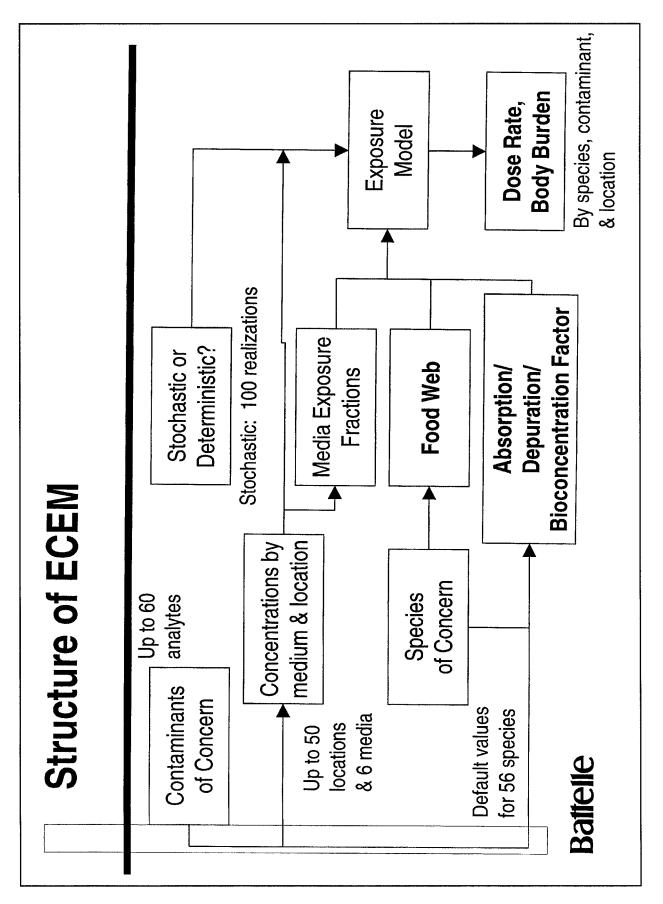
What is ECEM?

- An ecological risk assessment modeling tool

- Estimates exposures
  - from metals, organics, and/or radionuclides
  - in terrestrial and/or aquatic environments

- Based on a food-web architecture

- Helps environmental managers assess impacts as part of a regulatory or decision-making process
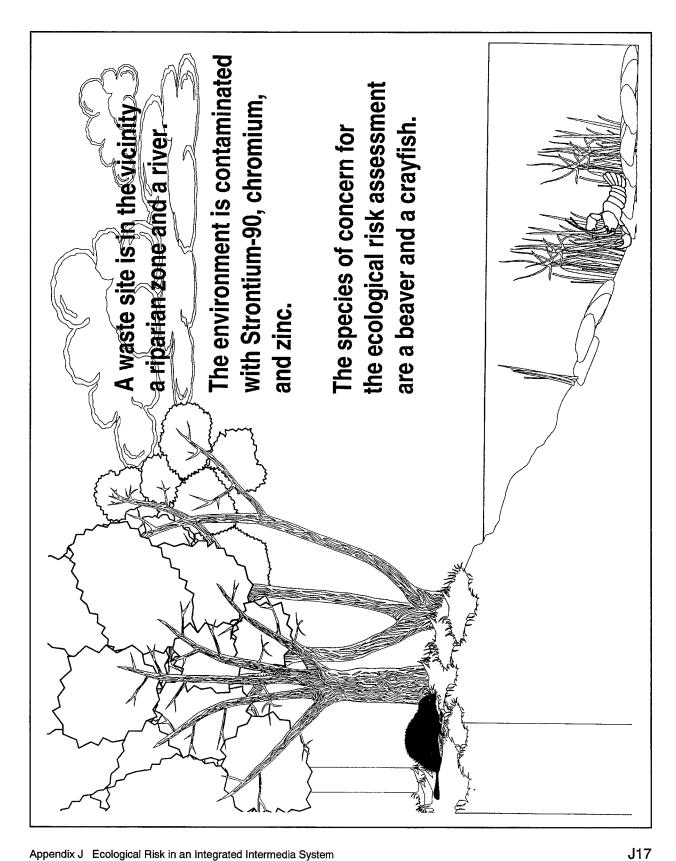
Battelle
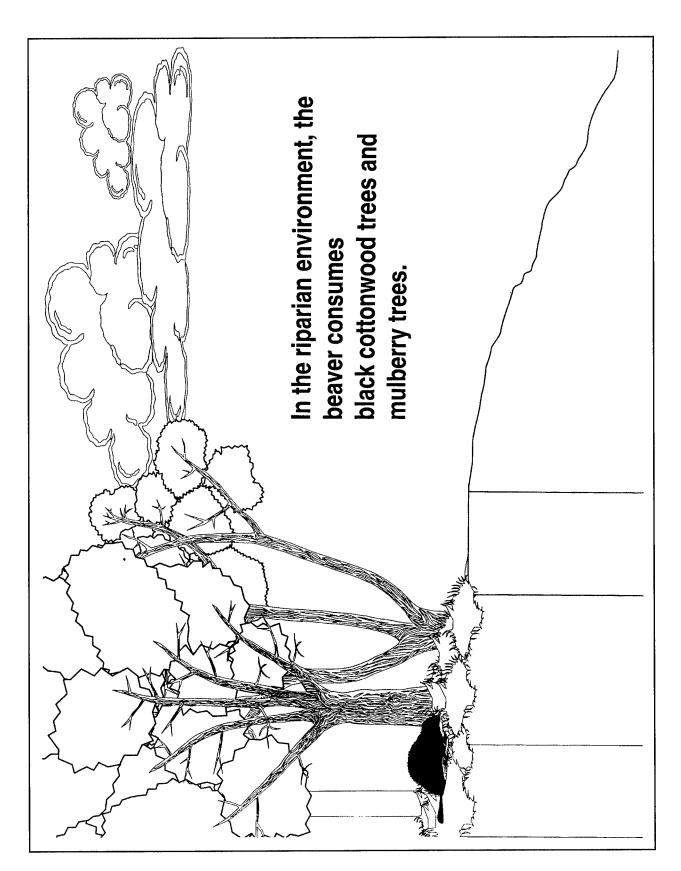
How does ECEM work?
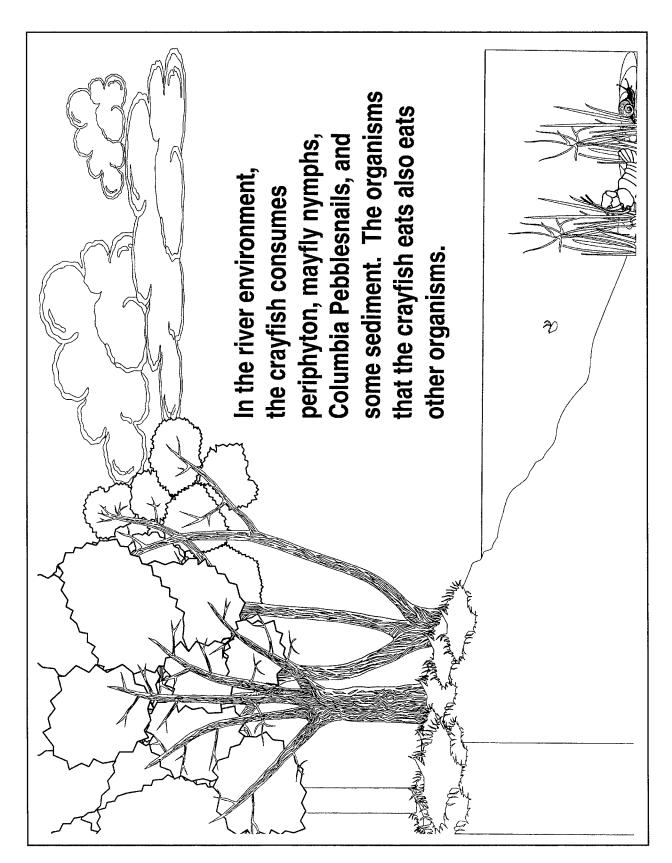
- User inputs
  - contaminants of interest
  - species of interest and species in food web
  - environmental data (e.g., contaminant concentrations in air, water and soil)

- Results of the model are
  - body burden or dose rate
  - compared to environmental benchmarks to calculate the environmental hazard quotient, or
  - used as input into human health assessments

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Structure of ECEM

Contaminants
of Concern

Up to 60
analytes

Stochastic or
Deterministic?

Stochastic: 100 realizations

Concentrations by
medium & location

Up to 50
locations
& 6 media

Media Exposure
Fractions

Food Web

Species
of Concern

Default values
for 56 species

Absorption/
Depuration/
Bioconcentration Factor

Exposure
Model

**Dose Rate,
Body Burden**

By species, contaminant,
& location

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Let's go through an example.......

What is the problem to be assessed?

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A waste site is in the vicinity a riparian zone and a river.

The environment is contaminated with Strontium-90, chromium, and zinc.

The species of concern for the ecological risk assessment are a beaver and a crayfish.

In the riparian environment, the beaver consumes black cottonwood trees and mulberry trees.

In the river environment, the crayfish consumes periphyton, mayfly nymphs, Columbia Pebblesnails, and some sediment. The organisms that the crayfish eats also eats other organisms.

That is, the food web definitions are:

- **Crayfish Consumption**
  - 30% Sediment
  - 50% Periphyton
  - 10% Mayfly
    - 10% Sediment
    - 30% Phytoplankton
    - 40% Periphyton
    - 12% Water Millfoil
    - 4% Hyallela
    - 4% Daphnia Magna
  - 10% Columbia Pebblesnail
    - 10% Sediment
    - 80% Periphyton
    - 10% Water Millfoil

- **Beaver Consumption**
  - 50% Black Cottonwood
  - 50% Mulberry

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The environmental data for this example:
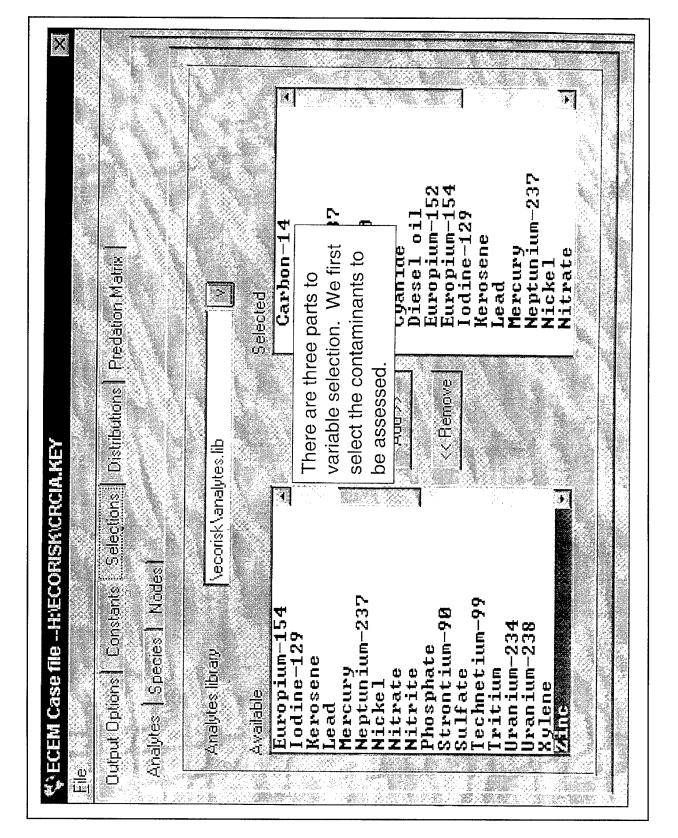
- ■ Media Data
  - • Pore Water
  - • Surface Water
  - • Sediment
  - • Soil
- ■ Internally-Calculated Concentrations
  - • Air Vapor
  - • Air Particulate
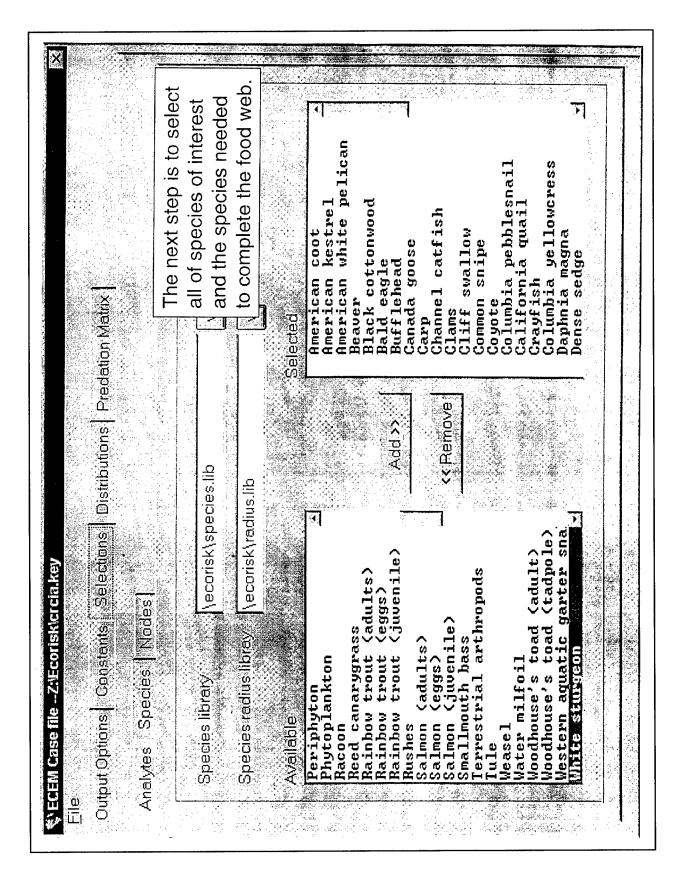
Battelle

Now that we have the basic problem defined,

Let's start the model...........
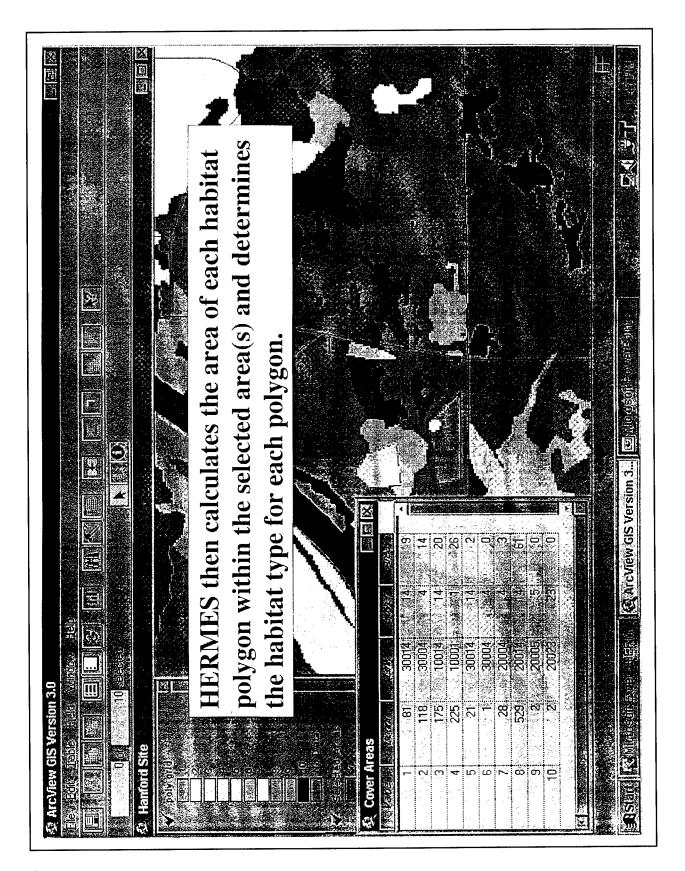
Battelle

ECEM Case file -- Z:\Ecorisk\crcia.key

File

Output Options | Constants | Selections | Distributions | Predation Matrix

Controls

Title of run: CRCIA - ECORISK Run Replicating the CRCIA Repor

Name of user: Paul W. Eslinger

Run WEB

Debug
- [ ] Nodes
- [ ] Species
- [ ] Constant
- [ ] Concentrations
- [ ] Generate
- [ ] Loop
- [ ] Analytes
- [X] Equations
- [ ] Correlations
- [X] Statistical Report
- [ ] Print stochastic def.
- [ ] Check input only

File Locations

Media data header: \ecorisk\CRCIA.cnh

Media data: \ecorisk\CRCIA.cnd

Output report: \ecorisk\CRCIA.RPT

Body burden report: \ecorisk\CRCIA.bur

Stats summary: \ecorisk\CRCIA.sta

We begin by naming the run and identifying the input library files and output files.

ECEM Case file -- Z:\Ecorisk\circia.key

File

Output Options | Constants | Selections | Distributions | Predation Matrix
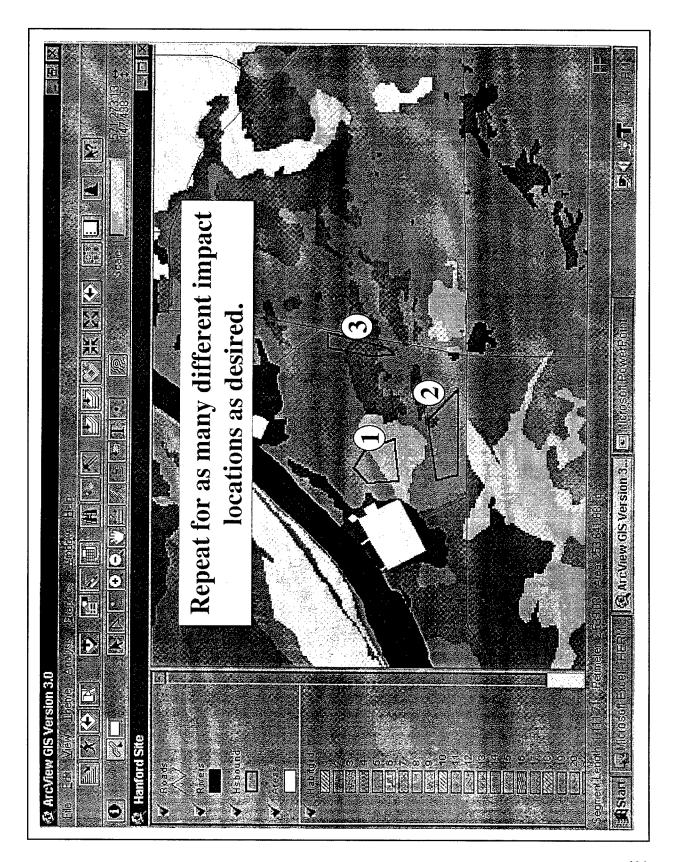
Cowherd function	0.05	
Exposure interval	790000000	sec
Universal gas constant	8.314	Pa-m^3/m
Respirable fraction	0.036	g/m^2-hr
Area of contamination	500	cm^2
Length of side of contamination	1000	m
Uptake fraction of tritium in plants	0.9	fraction
Delta in growth rate equation	0.002	
Beta in growth rate equation	0.25	
Gamma in respiration rate equation	0.2	
Phi in respiration rate equation	0.032	
Random seed value	446000	
Number of realizations	100	

The constant parameters are set on the next screen. The background appears green if the value is within the expected range.

ECEM Case file --H:\ECORISK\CRCIA.KEY

File

Output Options | Constants | Selections | Distributions | Predation Matrix

Analytes | Species | Nodes

Analytes library \ecorisk\analytes.lib

Available
Europium-154
Iodine-129
Kerosene
Lead
Mercury
Neptunium-237
Nickel
Nitrate
Nitrite
Phosphate
Strontium-90
Sulfate
Technetium-99
Tritium
Uranium-234
Uranium-238
Xylene
Zinc

Selected
Carbon-14
Cyanide
Diesel oil
Europium-152
Europium-154
Iodine-129
Kerosene
Lead
Mercury
Neptunium-237
Nickel
Nitrate

Add>>

<<Remove

There are three parts to variable selection. We first select the contaminants to be assessed.

ECEM Case file -- Z:\Ecorisk\crcia.key

File

Output Options | Constants | Selections | Distributions | Predation Matrix

Analytes | Species | Nodes

The next step is to select all of species of interest and the species needed to complete the food web.

Species library: \ecorisk\species.lib

Species:radius library: \ecorisk\radius.lib

Available
```
Periphyton
Phytoplankton
Racoon
Reed canarygrass
Rainbow trout (adults)
Rainbow trout (eggs)
Rainbow trout (juvenile)
Rushes
Salmon (adults)
Salmon (eggs)
Salmon (juvenile)
Smallmouth bass
Terrestrial arthropods
Tule
Weasel
Water milfoil
Woodhouse's toad (adult)
Woodhouse's toad (tadpole)
Western aquatic garter sna.
White sturgeon
```

Add >>   <<Remove

Selected
```
American coot
American kestrel
American white pelican
Beaver
Black cottonwood
Bald eagle
Bufflehead
Canada goose
Carp
Channel catfish
Clams
Cliff swallow
Common snipe
Coyote
Columbia pebblesnail
California quail
Crayfish
Columbia yellowcress
Daphnia magna
Dense sedge
```

The user can then visually examine the distribution of each habitat type.

HERMES then calculates the area of each habitat polygon within the selected area(s) and determines the habitat type for each polygon.

Repeat for as many different impact locations as desired.

Data are fed to the spreadsheet portion of the model for detailed analysis of habitat replacement costs and ecological values.

HERMES calculates total values and values for each habitat type.

Cover Class	Area	Description	Mit Cost	Species Value	Other Value	Total Value
1	26	Post-fire shrub-steppe on the Columbia River Plain Big Sagebrush/	$78,000	7188		$85,188
4	17	Bunchgrasses-Cheatgrass Big Sagebrush-Spiny	$153,000	10176		$163,176
5	0	Hopsage/ Bunchgrasses- Cheatgrass	$0	0		$0
14	92	Cheatgrass-Sandbergs Bluegrass	$0	2368		$2,368
23	0	Buildings/Parking Lots/ Gravel Pits/ Disturbed Areas	$0	0		$0
		Total Cost	$231,000	$19,732	$0	$250,732

Ecological Value

Habitat Replacement Cost

Alternatively, individual habitat polygons can be examined.

Mitigation / Habitat Replacement

- Based on user-defined values table

- User determines if habitat type is mitigable

- User defines mitigation thresholds (minimum area that would require compensation)

- Costs of different revegetation components are defined

- Can be altered for "what-if" analyses

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Microsoft Excel - HERMES.MOD

Cover Class	Description	Mitigable	Threshold	MCPH	#rubling#/ha	$/rubling#/ha	Native Grass or Herb Planting ($/ha)	Other Material Cost ($/ha)	Other costs explanation
1	Post-fire shrub-steppe on the Columbia River Plain		2	3000	500	4	1000	0	
2	Rabbitbrush/Bunchgrasses	N	0	0	0	0	0	0	
3	Rabbitbrush/Cheatgrass	N	0	0	0	0	0	0	
4	Big Sagebrush/Bunchgrasses-Cheatgrass		.05	9000	1000	4	1000	4000	Mature shrub transplant (10/ha @ 400$/each)
5	Big Sagebrush-Spiny Hopsage/Bunchgrasses-Cheatgrass		0.5	9000	1000	4	1000	4000	Mature shrub transplant (10/ha @ 400$/each)
6	Threetip Sagebrush/Bunchgrasses		0.5	5000	1000	4	1000	0	
7	Spiny Hopsage/Bunchgrasses		.05	9000	1000	4	1000	4000	Mature shrub transplant (10/ha @ 400$/each)
8	Spiny Hopsage/Cheatgrass	N	0	0	0	0	0	0	
9	Black Greasewood/Sandberg's Bluegrass		.05	1000	750	0	1000	0	
10	Winterfat/Bunchgrasses		.05	4000	1000	4	1000	0	
11	Winterfat/Cheatgrass	N	0	0	0	0	0	0	
12	Snow Buckwheat/Indian Ricegrass			1200		0	1000	200	snow buckwheat seed
13	Bunchgrasses			1000		0	1000	0	
14	Cheatgrass-Sandbergs Bluegrass	N	0	0	0	0	0	0	
15	Planted Non-Native Grass	N	0	0	0	0	0	0	
16	Bitterbrush/Bunchgrasses								Mature shrub transplant (10/ha @ ...)

Different cost estimates for tublings and shrubs......

Cover Class	Description	Mitigable	Threshold	MCPH	#tublings/ha	$/tubling	Native Grass or Herb Planting ($/ha)	Other Material Cost ($/ha)	Other costs explanation
1	Post-fire shrub-steppe on the Columbia River Plain	Y	2	3000	500	4	1000	0	
2	Rabbitbrush/Bunchgrasses	N	0	0	0	0	0	0	
3	Rabbitbrush/Cheatgrass	N	0	0	0	0	0	0	
4	Big Sagebrush/Bunchgrasses-Cheatgrass	Y	0.5	4000	1000	2	1000	1000	Mature shrub transplant (10/ha @ 100$/each)
5	Big Sagebrush-Spiny Hopsage/Bunchgrasses-Cheatgrass	Y	0.5	9000	1000	4	1000	4000	Mature shrub transplant (10/ha @ 400$/each)
6	Threetip Sagebrush/Bunchgrasses	Y	0.5	5000	1000	4	1000	0	
7	Spiny Hopsage/Bunchgrasses	Y	5	9000	1000	4	4000	4000	Mature shrub transplant (10/ha @ 400$/each)
8	Spiny Hopsage/Cheatgrass	N	0	0	0	4	1000	0	
9	Black Greasewood/Sandberg's Bluegrass	Y	0.5	4000	150	4	1000	0	
10	Winterfat/Bunchgrasses	Y	0.5	4000	1000	0	1000	0	
11	Winterfat/Cheatgrass	N	0	0	0	0	1000	0	
12	Snow Buckwheat/Indian Ricegrass	Y	2	1200	0	0	1000	200	Snow buckwheat seed
13	Bunchgrasses	N	3	1008	0	0	1000	0	
14	Cheatgrass-Sandberg's Bluegrass	N	0	0	0	0	0	0	
15	Planted Non-Native Grass	N	0	0	0	0	0	0	Mature shrub transplant (10/ha @
16	Bitterbrush/Bunchgrasses								

Cover Class	Area	Description	Total Species Value	Burrowing Owl	Coyote	Loggerhead Shrike	Northern Harrier	Pocket mouse	Sage Sparrow	Sagebrush Lizard
	26	Post-fire shrub-steppe on the Columbia River Plain	$7,188	$0	$0	$1,000	$0	$208	$780	$5,200
	17	Big Sagebrush/Bunchgrasses Cheatgrass	$10,176	$0	$0	$1,200	$0	$136	$2,040	$6,800
		Big Sagebrush-Spiny Hopsage/Bunchgrasses Cheatgrass	$0	$0	$0	$0	$0	$0	$0	$0
	14	Cheatgrass-Sandbergs Bluegrass	$2,368	$2,000	$0	$0	$0	$368	$0	$0
	92	Buildings/Parking Lots								
	23	Gravel Pits/Disturbed Areas	$0	$0	$0	$0	$0	$0	$0	$0
		Total	$19,732	$2,000	$0	$2,200	$0	$712	$2,820	$12,000

The "species value" is estimated for each habitat type and species combination by multiplying an estimated "unit value" by the estimated population size for each species.

Microsoft Excel - HERMES.MOD

File Edit View Insert Format Tools Data Window Help

Geneva   10

D8   =SUM(D2:D6)

Cover Class	Area	Description	Burrowing Owl	Coyote	Loggerhead Shrike	Northern Harrier	Pocket mouse	Sage Sparrow	Sagebrush Lizard
1	26	Post-fire Shrub-steppe on the Columbia River Plain	0.78	0.052	5.2	0.173333333	416	26	2600
4	17	Big Sagebrush/Bunchgrasses; Cheatgrass	0.68	0.034	6.8	0.113333333	272	98	3400
5	0	Big Sagebush-Spiny Hopsage/Bunchgrasses- Cheatgrass	0	0	0	0	0	0	0
14	92	Cheatgrass/Sandbergs Bluegrass	1.84	0.184	0	0.148888889	736	0	0
23	0	Buildings/Parking Lots/ Gravel Pits/ Disturbed Areas	0	0	0	0	0	0	0
		Total	3.30	0.27	12.0	0.43	14x0	3.3	0.0000

Similarly, population size could be the result of species-specific population models, but currently is a simple calculation that incorporates…..

Cov Class / Polygons / Cover Classes / Pop(CovClass)

ECEM Case file -- H:\ECORISK\CRCIA.KEY

File

Output Options | Constants | Selections | Distributions | Predation Matrix

Analytes | Species | Nodes

The nodes or locations where exposure will be analyzed are selected here.

Nodes library
\ecorisk\nodes.lib

Available

ND-011
ND-012
ND-013
ND-014
ND-015
ND-016
ND-017
ND-018
ND-019
ND-020
ND-021
ND-022
ND-023
ND-024
ND-025
ND-026
ND-027
ND-001

Apply >>

<< Remove

Selected

ND-001
ND-001
ND-002
ND-003
ND-004
ND-005
ND-006
ND-007
ND-008
ND-009
ND-010
ND-011
ND-012
ND-013
ND-014
ND-015
ND-016
ND-017

In the next menu screen, the user interface prompts you for the stochastic variables that need to be defined.

ECEM Case file --Z:\Ecorisk\crcia.key

File

Output Options | Constants | Selections | Distributions | F

Description of selected variable

Bioconcentration factor for vegetation of Cesium-137

Variable selection

```
BCFUEG of Carbon-14
KOW of Carbon-14
KDSW of Carbon-14 at node ND-001
KDSW of Carbon-14 at node ND-001
BCFUEG of Ammonia
KOW of Ammonia
KDSW of Ammonia at node ND-001
KDSW of Ammonia at node ND-001
KOW of Benzene
KDSW of Benzene at node ND-001
KDSW of Benzene at node ND-001
BCFUEG of Cesium-137
KOW of Cesium-137
KDSW of Cesium-137 at node ND-001
KDSW of Cesium-137 at node ND-001
BCFUEG of Chromium
KOW of Chromium
KDSW of Chromium at node ND-001
KDSW of Chromium at node ND-001
BCFUEG of Cobalt-60
KOW of Cobalt-60
KDSW of Cobalt-60 at node ND-001
KDSW of Cobalt-60 at node ND-001
BCFUEG of Copper
KOW of Copper
KDSW of Copper at node ND-001
KDSW of Copper at node ND-001
```

Distribution

Triangular

Lower bound

0.041

Upper bound

0.05

Mode

0.045

☐ Truncate

Truncation lower limit

0.0

Truncation upper limit

0.0

ECEM Case file --H:\ECORISK\CRCIA.KEY

File

Output Options | Constants | Selections | Distributions | Predation Matrix |

Description of selected variable

Soil-Water partition coefficient of Lead at node ND-001

Variable selection

The user interface gives you the list available stochastic distributions. Once you select a distribution, you will see the appropriate parameters to define the distribution.

Distribution

Triangular

Uniform
Discrete Uniform
Log Uniform (base 10)
Log Uniform (base e)
Triangular
Normal
Log Normal (base 10)
Log Normal (base e)

10000.0   cm^3/g

☐ Truncate

Truncation lower limit

0.0   cm^3/g

Truncation upper limit

0.0   cm^3/g

√ BCFUEG of
√ KOW of Car
√ KDSW of Ca
√ KDSW of Ca
√ BCFUEG of
√ KOW of Amm
√ KDSW of Am
√ KDSW of Am
√ KOW of Ben
√ KDSW of Benzene at node ND-001
√ KDSW of Benzene at node ND-001
√ BCFUEG of Cesium-137
√ KOW of Cesium-137
√ KDSW of Cesium-137 at node ND-0
√ KDSW of Cesium-137 at node ND-0
√ BCFUEG of Chromium
√ KOW of Chromium
√ KDSW of Chromium at node ND-001
√ KDSW of Chromium at node ND-001
√ BCFUEG of Cobalt-60
√ KOW of Cobalt-60

ECEM Case file -- Z:\Ecorisk\crcia.key

File

Output Options | Constants | Selections | Distributions | Predation Matrix

	American coot	American kestrel	American white pelica
American coot	0.0000	0.0000	0.000
American kestrel	0.0000		0.000
American white pelican	0.0000	0.0000	
Beaver	0.0000	0.0000	0.000
Black cottonwood	0.0000	0.0000	0.000
Bald eagle	0.0000	0.0000	0.000
Bufflehead	0.0000	0.0000	0.000
Canada goose	0.0000	0.0000	0.000
Carp	0.0000	0.0000	0.000
Channel catfish	0.0000	0.0000	0.000
Clams	0.0000	0.0000	0.000
Cliff swallow	0.0000	0.0000	0.000
Common poppy	00	0.0000	0.000
	00	0.0000	0.000
	00	0.0000	0.000
	00	0.0000	0.000
Daphnia magna		0.0000	0.000
Dense sedge	0.0000	0.0000	0.000
Fern	0.0000	0.0000	0.000

The predation matrix for the selected species in the food web is set here. The final column is a row sum that must total either 0 or 1.

ECEM Case file -- H:\ECORISK\CRCIA.KEY

File

Output Options | Constants | Selections | Distributions | Predation Matrix |

Controls

Title of run: CRCIA - ECORISK Run Replicating the CRCIA Rep

Name of user: Paul W. Eslinger

Run WEB

We are now all set to run the code by pressing

Debug

- [ ] Nodes
- [ ] Species
- [ ] Constant
- [ ] Concentrations
- [ ] Generate
- [ ] Loop
- [ ] Analytes
- [X] Equations
- [ ] Correlations
- [X] Statistical Report
- [ ] Print stochastic def.
- [ ] Check input only

File

Media data header   \ecorisk\CRCIA.cnh

Media data   \ecorisk\CRCIA.cmd

Output report   \ecorisk\CRCIA.RPT

Body burden report   \ecorisk\CRCIA.bur

Stats summary   \ecorisk\CRCIA.sta

What kind of results do you get from ECEM?

Identification			Minimum	5% Level	10% Level	25% Level	Median	75% Level	90% Level
ND-001	BLCTWD C14	BURDEN	3.928E-01	4.420E-01	4.625E-01	4.838E-01	5.211E-01	5.576E-01	6.040E-01
ND-001	BLCTWD C14	DOSRAD	1.006E-09	1.132E-09	1.184E-09	1.239E-09	1.334E-09	1.428E-09	1.546E-09
ND-001	CYLCRS C14	BURDEN	1.353E-01	1.499E-01	1.521E-01	1.635E-01	1.756E-01	1.869E-01	1.999E-01
ND-001	CYLCRS C14	DOSRAD	3.465E-10	3.838E-10	3.894E-10	4.187E-10	4.495E-10	4.784E-10	5.119E-10
ND-001	DENSDG C14	BURDEN	1.920E-01	2.161E-01	2.261E-01	2.365E-01	2.548E-01	2.726E-01	2.953E-01
ND-001	DENSDG C14	DOSRAD	4.917E-10	5.533E-10	5.789E-10	6.056E-10	6.523E-10	6.979E-10	7.560E-10
ND-001	FERN C14	BURDEN	1.920E-01	2.161E-01	2.261E-01	2.365E-01	2.548E-01	2.726E-01	2.953E-01
ND-001	FERN C14	DOSRAD	4.917E-10	5.533E-10	5.789E-10	6.056E-10	6.523E-10	6.979E-10	7.560E-10
ND-001	FUNGI C14	BURDEN	7.856E-02	8.840E-02	9.250E-02	9.677E-02	1.042E-01	1.115E-01	1.288E-01
ND-001	FUNGI C14	DOSRAD	2.012E-10	2.264E-10	2.368E-10	2.478E-10	2.669E-10	2.856E-10	3.093E-10
ND-001	MULBRV C14	BURDEN	3.928E-01	4.420E-01	4.625E-01	4.838E-01	5.211E-01	5.576E-01	6.040E-01
ND-001	MULBRV C14	DOSRAD	1.006E-09	1.132E-09	1.184E-09	1.239E-09	1.334E-09	1.428E-09	1.546E-09
ND-001	PERPHY C14	BURDEN	1.032E-01	1.179E-01	1.213E-01	1.269E-01	1.399E-01	1.517E-01	1.614E-01
ND-001	PERPHY C14	DOSRAD	2.641E-10	3.019E-10	3.106E-10	3.249E-10	3.582E-10	3.882E-10	4.132E-10
ND-001	PHYPLK C14	BURDEN	8.989E-02	9.820E-02	1.038E-01	1.116E-01	1.196E-01	1.297E-01	1.387E-01
ND-001	PHYPLK C14	DOSRAD	2.302E-10	2.515E-10	2.658E-10	2.857E-10	3.062E-10	3.321E-10	3.552E-10
ND-001	RCANGS C14	BURDEN	1.920E-01	2.161E-01	2.261E-01	2.365E-01	2.548E-01	2.726E-01	2.953E-01
ND-001	RCANGS C14	DOSRAD	4.917E-10	5.533E-10	5.789E-10	6.056E-10	6.523E-10	6.979E-10	7.560E-10
ND-001	RTRTEG C14	BURDEN	1.622E-01	1.806E-01	1.838E-01	1.958E-01	2.113E-01	2.243E-01	2.354E-01
ND-001	RTRTEG C14	DOSRAD	4.151E-10	4.622E-10	4.704E-10	5.013E-10	5.410E-10	5.743E-10	6.025E-10
ND-001	RUSHES C14	BURDEN	1.920E-01	2.161E-01	2.261E-01	2.365E-01	2.548E-01	2.726E-01	2.953E-01
ND-001	RUSHES C14	DOSRAD	4.917E-10	5.533E-10	5.789E-10	6.056E-10	6.523E-10	6.979E-10	7.560E-10
ND-001	SALMAD C14	BURDEN	1.890E-01	1.953E-01	2.007E-01	2.247E-01	2.410E-01	2.620E-01	2.724E-01
ND-001	SALMAD C14	DOSRAD	4.838E-10	5.001E-10	5.138E-10	5.753E-10	6.170E-10	6.708E-10	6.974E-10
ND-001	SALMEG C14	BURDEN	1.552E-01	1.771E-01	1.809E-01	1.943E-01	2.092E-01	2.277E-01	2.385E-01
ND-001	SALMEG C14	DOSRAD	3.973E-10	4.533E-10	4.631E-10	4.974E-10	5.356E-10	5.830E-10	6.105E-10
ND-001	TULE C14	BURDEN	2.706E-01	2.998E-01	3.042E-01	3.271E-01	3.511E-01	3.737E-01	3.998E-01
ND-001	TULE C14	DOSRAD	6.928E-10	7.676E-10	7.787E-10	8.373E-10	8.989E-10	9.568E-10	1.024E-09
ND-001	WMLFOL C14	BURDEN	1.035E-01	1.116E-01	1.147E-01	1.236E-01	1.303E-01	1.384E-01	1.418E-01
ND-001	WMLFOL C14	DOSRAD	2.649E-10	2.856E-10	2.937E-10	3.164E-10	3.335E-10	3.544E-10	3.631E-10
ND-001	BEAVER C14	BURDEN	3.645E+00	4.056E+00	4.291E+00	4.548E+00	4.944E+00	5.267E+00	5.420E+00
ND-001	BEAVER C14	DOSRAD	9.330E-08	1.056E-08	1.098E-08	1.162E-08	1.266E-08	1.348E-08	1.388E-08
ND-001	CPBLSN C14	BURDEN	2.624E-01	3.078E-01	3.213E-01	3.377E-01	3.575E-01	3.758E-01	3.927E-01
ND-001	CPBLSN C14	DOSRAD	6.717E-10	7.881E-10	8.225E-10	8.645E-10	9.152E-10	9.621E-10	1.005E-09
ND-001	DAPMAG C14	BURDEN	2.541E-01	2.717E-01	2.869E-01	3.112E-01	3.308E-01	3.525E-01	3.822E-01
ND-001	DAPMAG C14	DOSRAD	6.505E-10	6.957E-10	7.344E-10	7.966E-10	8.469E-10	9.025E-10	9.785E-10

System Requirements for ECEM

- **Software**
  - Windows Application
  - Visual Basic User Interface
  - Fortran 90 Code
- **Hardware**
  - PC running Windows 95
  - 40 MB RAM
  - 150 MB Disk Space

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For more information contact:

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"HERMES"
Health and Ecological Risk Management and Evaluation System

An Integrated Environmental Decision Support Tool

Battelle

Developed by
Pacific Northwest National Laboratory
for the U. S. Department of Energy

For information contact:

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Background

- Need to evaluate ecological and monetary trade-offs on the Hanford Site between remediation, restoration, and land use options before action is taken

- Ecological risk assessments normally focus on contaminant effects on wildlife, ignore impacts of the remediation action itself

- Need to connect different decision dimensions using common units

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Objectives

- Develop a GIS-based decision support tool that concisely describes the current environmental landscape and can be used to make decisions

- Develop a tool that provides ecological information in a format directly comparable to other decision dimensions—including project costs and human health and wildlife risks

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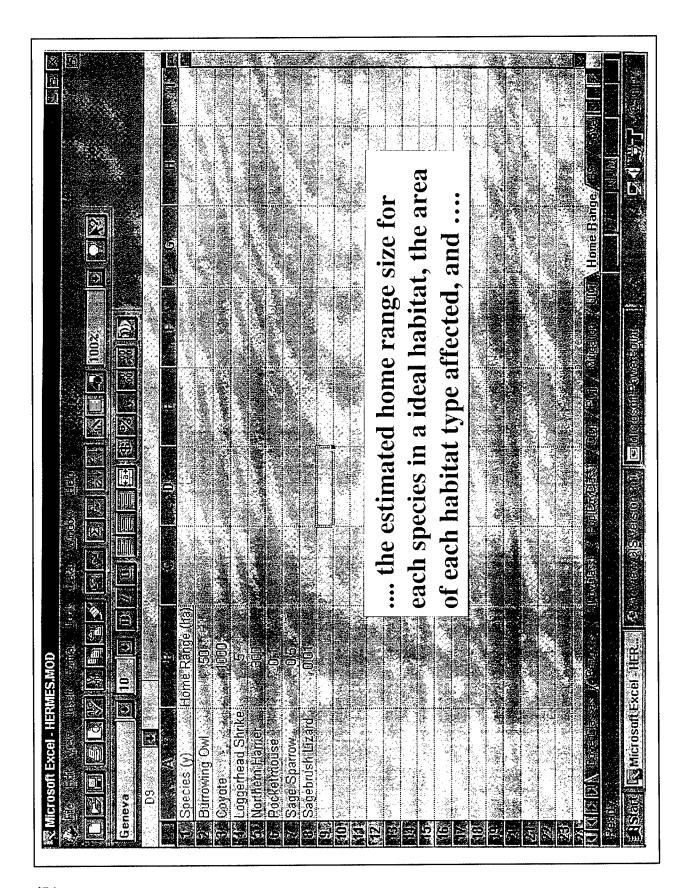
Environmental Decision Making Made Easier

- HERMES—a flexible visualization and analysis program—helps environmental restoration, land use, and resource managers make decisions

- HERMES allows interactive evaluation of impacts with user-selected restoration costs and species values

- Other decision dimensions, such as human health, eco-risk, and ecosystem function can be included as extensions to the model

Battelle
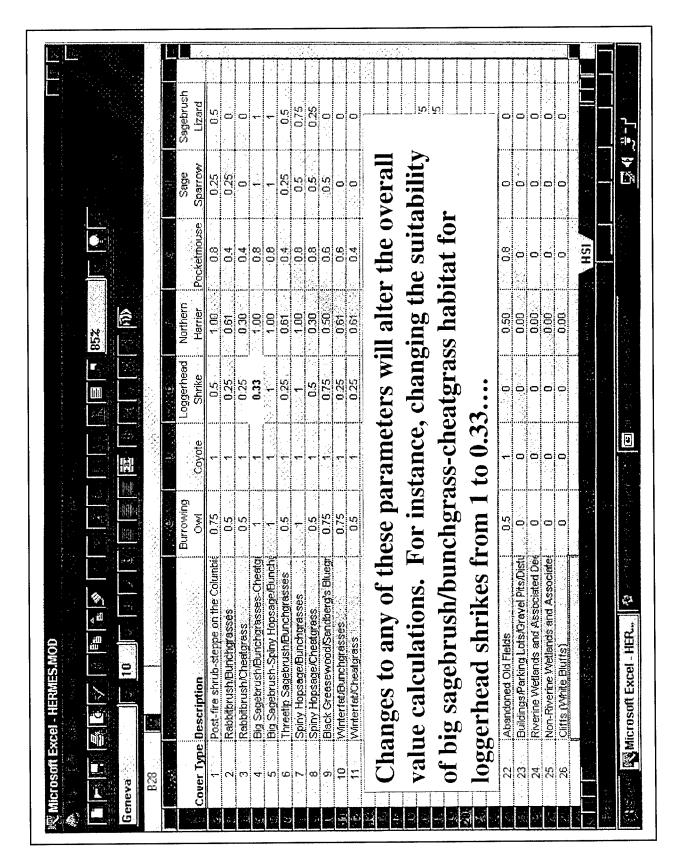
Advantages
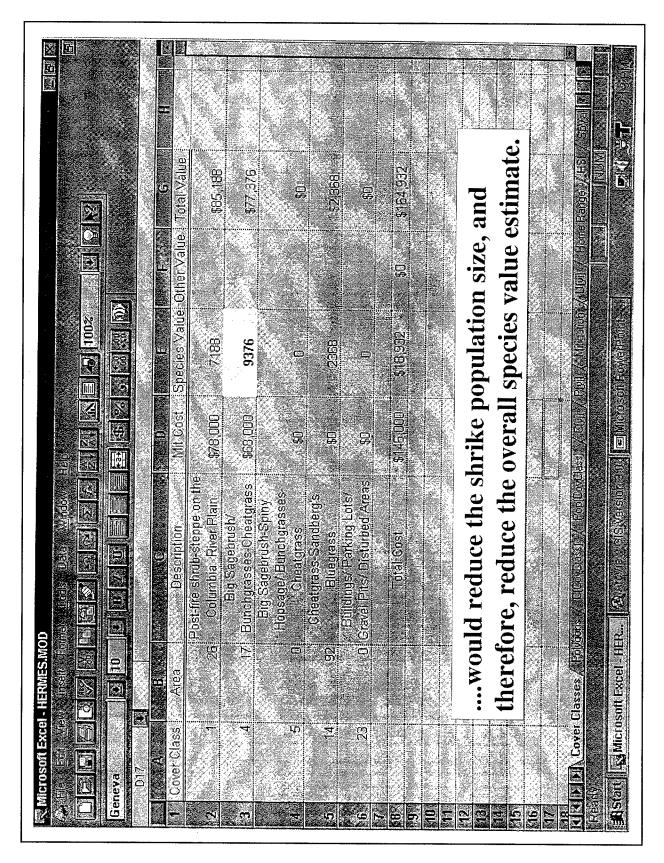
■ Usable - links with user's existing databases

■ Portable - can run on a laptop computer, which facilitates public involvement

■ Easily manipulated - user can control data input values

■ Expandable - modular design allows inclusion of additional decision dimensions

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Microsoft Excel - HERMES.MOD

Geneva

D9

A	Home Range (ha)
Species (y)	
Burrowing Owl	50
Coyote	1000
Loggerhead Shrike	5
Northern Harrier	
Pocketmouse	
Sage Sparrow	0.5
Sagebrush Lizard	0.01

... the estimated home range size for each species in a ideal habitat, the area of each habitat type affected, and ....

Home Range

Start   Microsoft Excel - HER...

.... the estimated suitability of each habitat type for each species.

Cover Type	Description	Burrowing Owl	Coyote	Loggerhead Shrike	Northern Harrier	Pocketmouse	Sage Sparrow	Sagebrush Lizard
1	Post-fire shrub-steppe on the Columbia	0.75	1	0.5	1.00	0.8	0.25	0.5
2	Rabbitbrush/Bunchgrasses	0.5	1	0.25	0.61	0.4	0.25	0
3	Rabbitbrush/Cheatgrass	0.5	1	0.25	0.30	0.4	0	0
4	Big Sagebrush/Bunchgrasses-Cheatgr	1	1	1	1.00	0.8	1	1
5	Big Sagebrush-Spiny Hopsage/Bunch	1	1	1	1.00	0.8	1	1
6	Threetip Sagebrush/Bunchgrasses	0.5	1	0.25	0.61	0.4	0.25	0.5
7	Spiny Hopsage/Bunchgrasses	1	1	1	1.00	0.8	0.5	0.75
8	Spiny Hopsage/Cheatgrass	0.5	1	0.5	0.30	0.8	0.5	0.25
9	Black Greasewood/Sandberg's Bluegr	0.75	1	0.75	0.50	0.6	0.5	0
10	Winterfat/Bunchgrasses	0.75	1	0.25	0.61	0.6	0	0
11	Winterfat/Cheatgrass	0.5	1	0.25	0.61	0.4	0	0
12	Snow Buckwheat/Indian Ricegrass	1	1	0.25	0.61	0.8	0	0
13	Bunchgrasses	0.75	1	0.25	0.30	0.6	0	0
14	Cheatgrass-Sandberg's Bluegrass	0.5	1	0	0.24	0.4	0	0
15	Planted Non-Native Grass	0.25	1	0	0.24	0.4	0	0
16	Bitterbrush/Bunchgrasses-Sand Dune	0.5	1	0.75	1.00	0.8	0.5	0.75
17	Bitterbrush/Cheatgrass	0.5	1	0.5	0.50	0.8	0.25	0.25
18	Alkali Saltgrass-Cheatgrass	0.25	1	0	0.50	0.4	0	0
19	Riparian	0.5	1	0	0.61	1	0	0
20	Basalt Outcrops	0.25	1	0	0.61	0.2	0	0
21	Agricultural Areas	0.5	1	0	0.50	0.4	0	0
22	Abandoned Old Fields	0.5	1	0	0.50	0.8	0	0
23	Buildings/Parking Lots/Gravel Pits/Distu	0	0	0	0.00	0	0	0
24	Riverine Wetlands and Associated De	0	0	0	0.00	0	0	0
25	Non-Riverine Wetlands and Associate	0	0	0	0.00	0	0	0
26	Cliffs (White Bluffs)	0	0	0	0.00	0	0	0

HSI

Geneva 10

B28

Cover Type Description	Burrowing Owl	Coyote	Loggerhead Shrike	Northern Harrier	Pocketmouse	Sage Sparrow	Sagebrush Lizard
1 Post-fire shrub-steppe on the Columbia	0.75	1	0.5	1.00	0.8	0.25	0.5
2 Rabbitbrush/Bunchgrasses	0.5	1	0.25	0.61	0.4	0.25	0
3 Rabbitbrush/Cheatgrass	0.5	1	0.25	0.30	0.4	0	0
4 Big Sagebrush/Bunchgrasses-Cheatgr	1	1	**0.33**	1.00	0.8	1	1
5 Big Sagebrush-Spiny Hopsage/Bunch	1	1	1	1.00	0.8	1	1
6 Threetip Sagebrush/Bunchgrasses	0.5	1	0.25	0.61	0.4	0.25	0.5
7 Spiny Hopsage/Bunchgrasses	1	1	1	1.00	0.8	0.5	0.75
8 Spiny Hopsage/Cheatgrass	0.5	1	0.5	0.30	0.8	0.5	0.25
9 Black Greesewood/Sandberg's Blueg	0.75	1	0.75	0.50	0.6	0.5	0
10 Winterfat/Bunchgrasses	0.75	1	0.25	0.61	0.6	0	0
11 Winterfat/Cheatgrass	0.5	1	0.25	0.61	0.4	0	0
22 Abandoned Old Fields	0.5	1	0	0.50	0.8	0	0
23 Buildings/Parking Lots/Gravel Pits/Distu	0	0	0	0.00	0	0	0
24 Riverine Wetlands and Associated Deg	0	0	0	0.00	0	0	0
25 Non-Riverine Wetlands and Associatec	0	0	0	0.00	0	0	0
26 Cliffs (White Bluffs)	0	0	0	0.00	0	0	0

HSI

Changes to any of these parameters will alter the overall value calculations. For instance, changing the suitability of big sagebrush/bunchgrass-cheatgrass habitat for loggerhead shrikes from 1 to 0.33....

Microsoft Excel - HER...

Microsoft Excel - HERMES.MOD

File Edit View Insert Format Tools Data Window Help

Geneva   10

D17

	A Cover Class	B Area	C Description	D Mit Cost	E Species Value	F Other Value	G Total Value
1			Post-fire shrub-steppe on the				
2	1	26	Columbia River Plain / Big Sagebrush/	$78,000	7188		$85,188
3	4	17	Bunchgrasses-Cheatgrass / Big Sagebrush-Spiny	$68,000	9376		$77,376
4	5	0	Hopsage/ Bunchgrasses/ Cheatgrass	$0	0		$0
5	14	92	Cheatgrass-Sandberg's Bluegrass	$0	2368		$2,868
6	23	0	Buildings/ Parking Lots/ Gravel Pits/ Disturbed Areas	$0	0		$0
7							
8			Total Cost	$145,000	$18,932	$0	$164,932

...would reduce the shrike population size, and therefore, reduce the overall species value estimate.

Cover Classes   Polygon

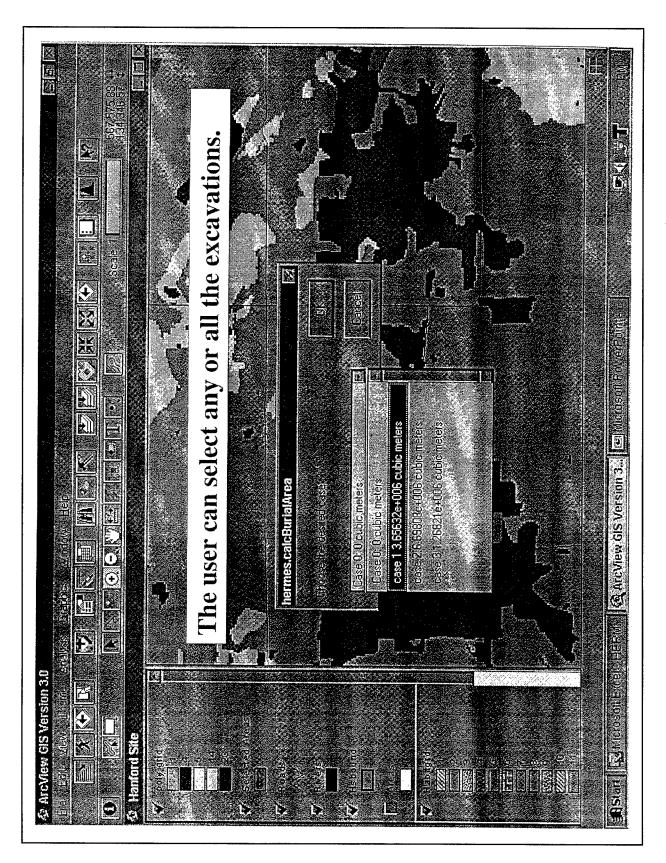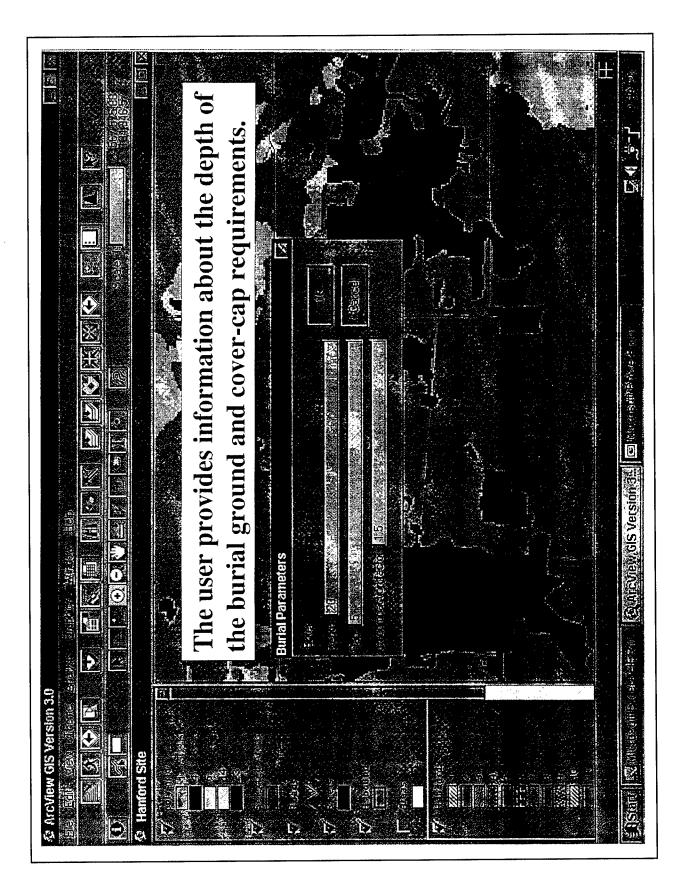Microsoft Excel - HER...

Ready

Start

HERMES Extensions

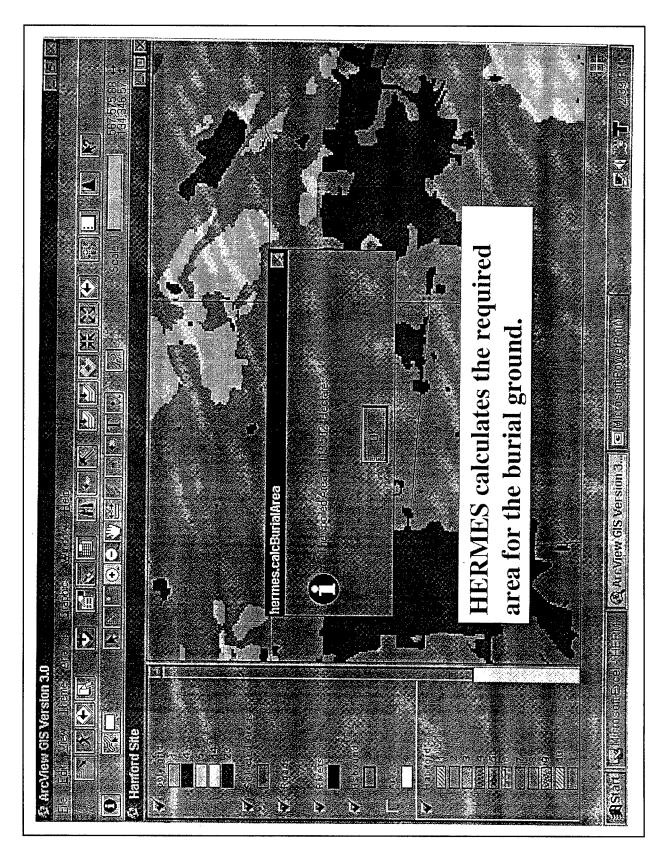- One extension allows user to compare ecological impacts of alternative burial sites for waste site remediation projects

- HERMES estimates the area requirement for specified amounts of material and depth of proposed burial ground

- Side slopes and spoils storage areas taken into account

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We will bury our waste in a different part of the Hanford Site.

A HERMES-specific tool performs the required calculations.

The user can select any or all the excavations.

The user provides information about the depth of the burial ground and cover-cap requirements.

HERMES calculates the required area for the burial ground.

The user selects a burial ground location and draws one side. HERMES automatically calculates the other dimension.

HERMES then identifies the habitat types within the selected site and estimates the area of each habitat polygon. The data are then passed to the spreadsheet component ....

Microsoft Excel - HERMES.MOD

Cover Class	Area	Description	Mit. Cost	Species Value	Other Value	Total Value
1	38	Post-fire shrub-steppe on the Columbia River Plain	$114,000	124444		$126,444
5	81	Big Sagebrush-Spiny Hopsage/Bunchgrasses-- Cheatgrass	$729,000	55168		$784,168
		Total Cost	$843,000	$67,...012	$0	$910,612

900 $K -- OUCH!!!

E13

	Cover Class	Area	Description	Mit Cost	Species Value	Other Value	Total Value
1							
2	5	17	Big Sagebrush-Spiny Hopsage-Bunchgrasses-Cheatgrass	$153,000	10176		$163,176
3	14	102	Cheatgrass-Sandbergs Bluegrass	$0	4408		$4,408
4							
5			Total Cost	$153,000	$14,584	$0	$167,584

Still expensive, but better.

Potential Extensions

- Analyze habitat value rather than $$ value

- Restore site to any user-selected cover type, regardless of original cover type

- Calculate borrow site dimensions and associated ecological costs

- Calculate engineering costs for infrastructure development (i.e., roads, utilities)

- Include cultural resource concerns

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Use in Risk Assessment

- Exploring integrating HERMES and MEPAS within FRAMES to allow for spatial assessment of ecological/human health risk

- MEPAS would provide spatial grid of contaminant concentrations

- HERMES would provide the area of each habitat type at each concentration level

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Appendix J   Ecological Risk in an Integrated Intermedia System

Use in Risk Assessment - cont'd

- Output of MEPAS/HERMES integration will be used to predict potentially affected species and the number of affected individuals at each concentration level

- Predict changes in habitat value over time due to the contaminants

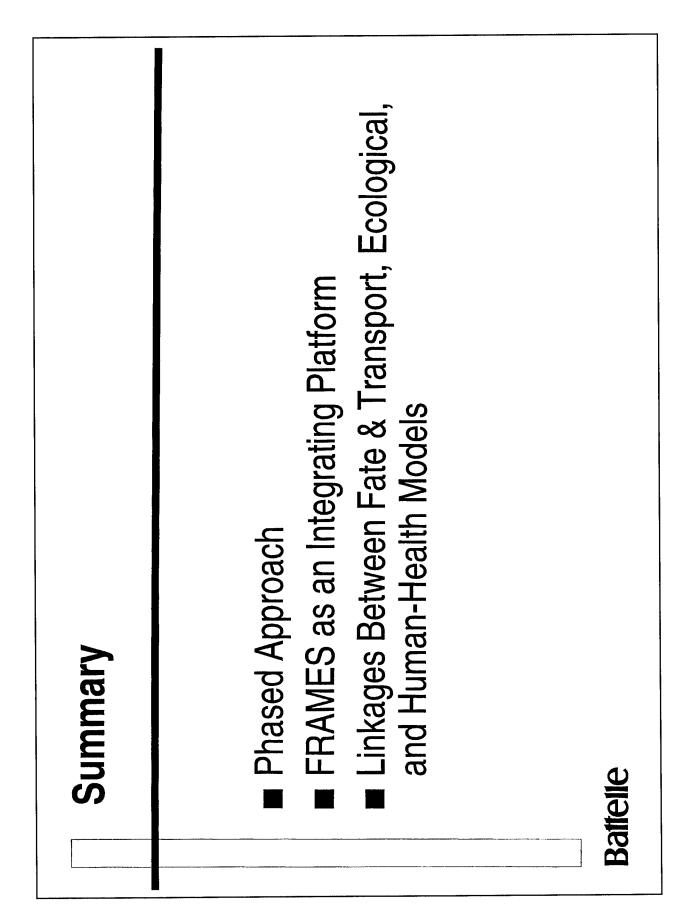- Mitigation decisions could be based on habitat value rather than cost-to-replace

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Requirements for Adaptation of HERMES to Other Settings

- Rastorized GIS map of habitat/cover types

- Site-specific framework for habitat restoration / mitigation decision making

- Estimates of costs to perform actions

- List of indicator species

- Estimates of home range and habitat suitability matrix for each species

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Summary

- Phased Approach

- FRAMES as an Integrating Platform

- Linkages Between Fate & Transport, Ecological, and Human-Health Models

Battelle

Appendix K
Exposure Assessment - Trophic Transfer to Birds

This appendix contains the presentation documents for "Exposure Assessment - Trophic Transfer to Birds" by David Glaser - Quantitative Environmental Analysis.
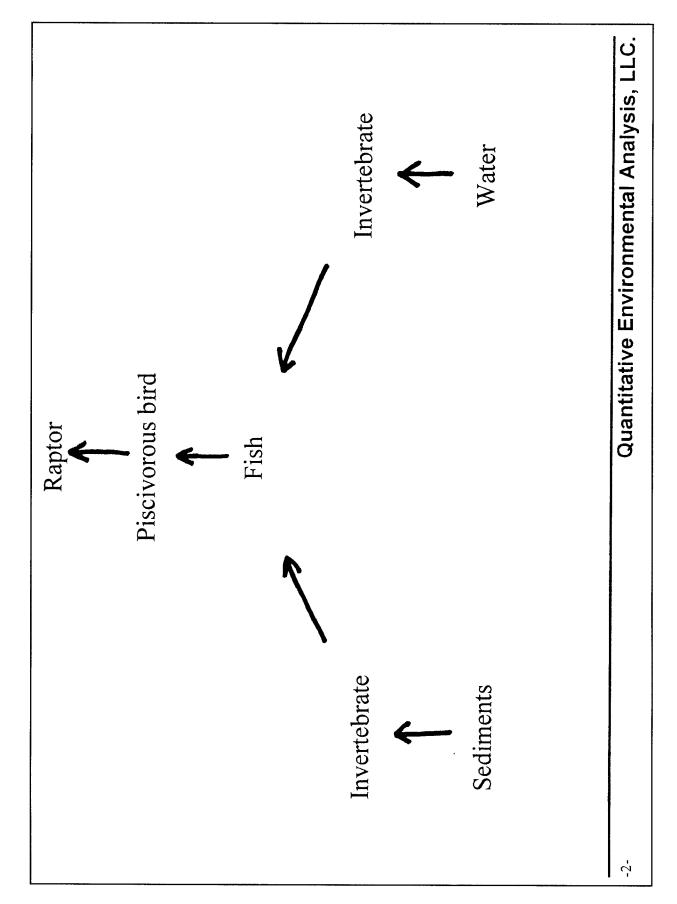
Exposure Assessment - Trophic Transfer to Birds

David Glaser

Quantitative Environmental Analysis, LLC.

Montvale, New Jersey

Quantitative Environmental Analysis, LLC.

-1-

1. Why quantify trophic transfer to birds?

Quantitative Environmental Analysis, LLC.

-3-

- to compute contaminant levels in species of interest

Bald eagles in the Southern California Bight

Prey			Bald eagle
Species	% of Diet	Measured DDE Conc. (whole body)	Computed DDE Conc. (eggs)
Fish + invertebrates	86	0.11	
Sea lions	2.7	26.	
Western gulls	2.6	8.3	37
Other gulls	0.9	5.4	
Water birds	6.2	1.7	
Land birds	0.9	1.4	

Contaminant levels can be used to assess the potential for toxicity.

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-4-

- to establish pathways of contamination

Bald eagles in the Southern California Bight

Prey		
Species	% of Diet	Measured DDE Conc.
Fish + invertebrates	86	0.11
Sea lions	2.7	26.
Western gulls	2.6	8.3
Other gulls	0.9	5.4
Water birds	6.2	1.7
Land birds	0.9	1.4

↑

Bald eagle	
Computed DDE Conc.	Measured DDE Conc.
37	36 (27-45)

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- to project future concentrations

Sample Projection

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- to estimate the potential for effects on population dynamics

Bioaccumulation Analysis

Exposure Conc.

Conc. in birds

Conc./Response Relationship

Impact on reproduction or survival

Pop. dynamics model

Impact on pop. dynamics

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Resident Fish Prey

Bald Eagle Eggs

Dashed lines: Model: +/- 2 standard deviations of Monte Carlo results
Solid lines and shaded area: Data +/- 2 standard errors

Bioaccumulation can be computed in several ways:

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Appendix K   Exposure Assessment - Trophic Transfer to Birds

Trophic transfer ratios, bioaccumulation factors

Ratios of DDE Levels in the Eggs of Predatory and Piscivorous Birds and Their Prey

Species	Weight (kg)	Prey	Source of Birds (study duration)	Movement	Ratio Between Compartments	Age of Egg	Reference
Peregrine Falcon	1.0	Birds	Yukon River, AK	migratory	16	unknown	Cade et al. 1968
Peregrine Falcon	1.0	Birds	Rocky Mountains, CO, AZ and NM	at least weakly migratory	23	addled eggs; variable age	Enderson et al. 1982
Peregrine Falcon	1.0	Birds	Rocky Mountains, CO, AZ and NM	migratory	6.8	addled eggs; reported ppm dry with percent water factor	Ellis et al. 1989
Bald Eagle	4.5	Birds	Klamath Basin, OR	resident	47	variable - corrected to fresh	Frenzel 1985
Double-crested Cormorant	2.1	Fish	Lake Huron	migratory	57	fresh	Weseloh et al. 1983

Notes: Wet weight basis
w.b. = whole body

- Steady-state model

Great Lakes Initiative

$$WV = \frac{TD}{F \times BAF} \times \frac{1}{UF} \qquad (1)$$

WV = wildlife water quality value (pg/L)
TD = toxic dose (mg/kg-day)
UF = uncertainty factor
F = food ingestion rate (kg/kg-day)
BAF = bioaccumulation factor (L/kg wet weight)

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Appendix K   Exposure Assessment - Trophic Transfer to Birds

- Time-variable simulation model

$$\frac{dc}{dt} = \alpha Cc_p - Kc - Ec$$

Eggs

ppm wet wt

Female

ppm wet wt

Age (years)

Concentration of p,p'DDE in a female bald eagle and in her eggs

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Strengths

| Simplicity | Species-specific parameterization Included | Changes in relative importance of sources can be evaluated | Reduced uncertainty |

BAFs → **Steady-state model** → **Time-variable model** → **Calibrated model**

Limitations

| species-specific food web, bioenergetics, migration, foraging behavior, life-cycle accumulation, temporal changes in exposure sources and levels | life-cycle accumulation, temporal changes in exposure sources and levels | Requires modeling capability and information on parameters | Requires site-specific data |

UNCERTAINTY DECREASES

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Uncertainty

- Uncertainty analysis for calibrated and uncalibrated models differ.

- Calibration reduces uncertainty by restricting the parameter sets that are consistent with field measurements.

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REPORT DOCUMENTATION PAGE

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Fate & Effects Advisory Committee (FEAC) identified the need for the development of models capable of providing information relating to the fate and effects of Military Relevant Compounds (MRCs) on both ecological and human resources. Requirements for better modeling capabilities of contaminant concentration over time for risk assessment were stated. In an effort to address the requirement, a work unit was initiated for the development of an Army Risk Assessment Modeling System (ARAMS). This system will incorporate other research efforts conducted in the Fate & Effects Research Program and will enable thorough evaluation of ecological and human risk assessments.

The ARAMS will be developed for the purpose of conducting ecological and human risk assessments. Development of this system will incorporate current state-of-the-art modeling technologies and will further utilize concurrent research efforts in the Fate and Effects Research Program. ARAMS is a tool to characterize, integrate, and estimate ecological risk. The system will provide several tiers of complexity such that screening-level and complex model issues can be addressed. The system will include: (a) screening-level assessments based on simple exposure-response relationships and limited spatial and temporal scales, (b) an expanded assessment

(continued)

15. SUBJECT TERMS
 ARAMS, Ecological and human health, Fate and effects, Risk assessment

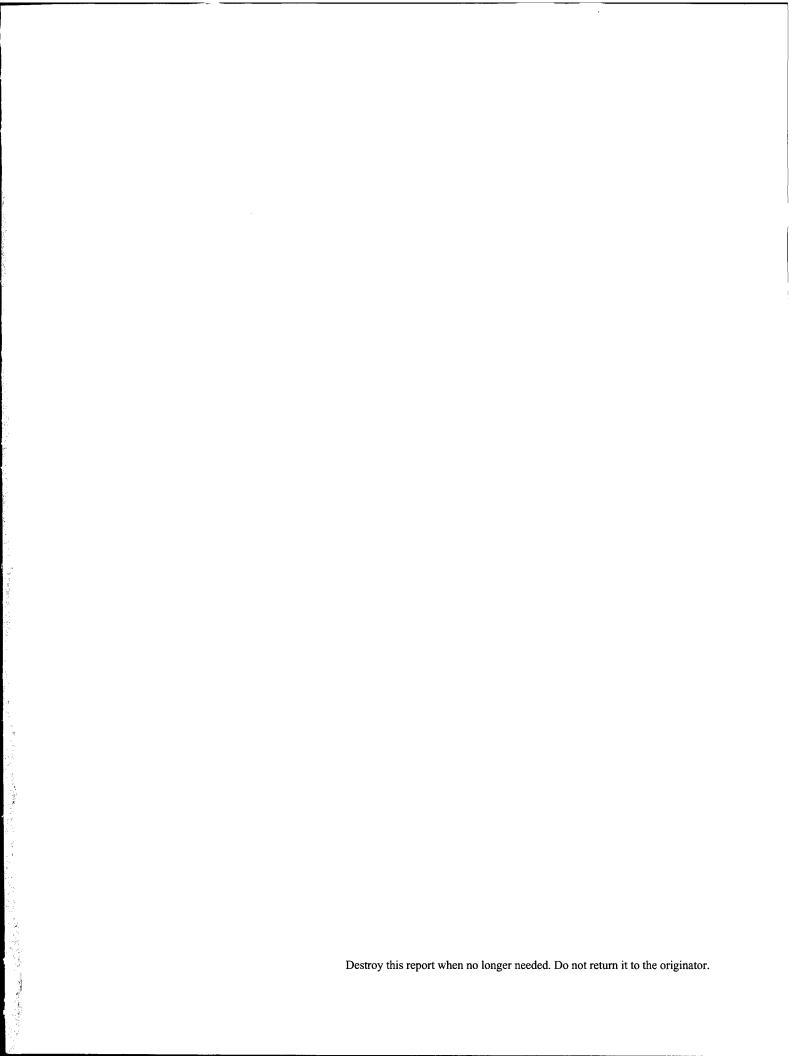| 16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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14. ABSTRACT (Concluded)

capability based on linkage of more rigorous exposure and ecological assessment techniques, and (c) linkage of ecological risk, comprehensive exposure models, and integrated temporal-spatial exposure, . . . i.e., probabilistic estimate of exposure for individuals/population in time and space.

The objective of this workshop was to ascertain the current state of the art in risk assessment modeling and to facilitate discussion of the components required for an ARAMS.

The development of ARAMS is anticipated to take several years to complete. One last major point discussed at the workshop was the necessity of choosing a proper location to test the system. A site would have to be chosen with a plethora of data such that screening- and comprehensive-level approaches for risk assessment for both ecological and human risk could be validated.